Fecal Coliform TMDL for Mill Creek Watershed, Virginia

Submitted by

Virginia Department of Environmental Quality

Virginia Department of Conservation and Recreation

Prepared by

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Executive Summary

This report presents the development of a Fecal Coliform TMDL for the Mill Creek watershed. Mill Creek is a tributary of the New River and is a part of the Upper New River Basin, hydrologic unit code (HUC) 05050001. The Mill Creek watershed is approximately 9,308 acres or 14.54 square miles. The watershed is located in the southwestern section of Montgomery County, Virginia. State Highway 8 (SH-8) runs through the western section of the watershed in a southerly direction. SH-8 connects the Town of Riner, which is located in the Mill Creek watershed, to Interstate 81 (I-81).

Mill Creek was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the fecal coliform bacteria water quality standard. Virginia's Water Quality Standards, Section 9 VAC 25-260-170, states that fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-period day, or a fecal coliform bacteria level of 1000 per 100 ml at anytime. Virginia Department of Environmental Quality (DEQ) recorded fecal coliform bacteria violations in 11 out of the 18 samples collected at Station 9-MLC005.44, and 3 out of the 6 samples collected Station 9-MLC002.59. Because of these violations, Mill Creek does not support primary contact recreation. Primary contact recreation includes swimming, wading, and fishing.

Land use characterization was based on data provided by DCR for the Mill Creek watershed. DCR developed this digital land use/land cover data using satellite images or digital ortho quarter quads (DOQQ) and extensive ground truthing. The dominant land uses in the Mill Creek watershed are improved pasture, forest, and cropland. The improved pasture accounts for 61% of the watershed land area. Forest accounts for 22% of the watershed. Cropland accounts for 10% of the watershed. The combination of these three land uses account for 93% of the land area of the watershed.

Mill Creek flows through a rural setting. Potential sources of fecal coliform include point sources and nonpoint (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven. For example, fecal coliform bacteria from the land-based sources (agricultural and urban runoff) will be most critical during wet weather conditions. The failed septic system loading is considered constant over time but it will be most critical during dry weather and stream low-flow conditions.

The potential sources of fecal coliform in the watershed were identified and characterized. These sources include one permitted point source, failed septic systems and straight pipes, livestock, wildlife, pets, and land application of manure.

An inventory of the livestock residing in the Mill Creek watershed was conducted using data and information provided from the DCR nutrient management specialist, Skyline Soil and Water Conservation District, Natural Resources Conservation Service (NRCS), and field surveys. Based on the inventory of livestock in the Mill Creek watershed, it was determined that:

- five dairy operations exist in the watershed,
- beef cattle operations exist throughout the watershed,
- no poultry operations exist in the watershed,
- no swine operations exist in the watershed, and
- other livestock includes horses and sheep.

In the Mill Creek watershed, two bacteria source tracking sampling stations were set up and water quality samples were collected and analyzed on a monthly basis from January to December 2001. Three categories of sources were considered: human, wildlife, and livestock. The BST results indicate fecal coliform bacteria from human, livestock, and wildlife are present in Mill Creek. The human signature ranged from 0 to 38%; the wildlife signature ranged from 0 to 67%; and the livestock signature ranged from 27% to 100%.

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the instream water quality conditions of Mill Creek under varying scenarios of rainfall and fecal coliform loading. The results from the developed Mill Creek model were used to develop the TMDL allocations. The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds;
- entering the physical data that describe each subwatershed and stream segment; and
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loadings in the watershed.

The Mill Creek watershed was delineated into 21 smaller subwatersheds to represent the watershed characteristics and to improve the HSPF model's accuracy. This delineation was based on the topographic characteristics using the Digital Elevation Model (DEM), the stream reaches using the RF3 data, and the location of stream flow and instream water quality monitoring stations.

Since no stream flow monitoring data on the Mill Creek watershed exist, the paired watershed approach was used to set up and calibrate the HSPF model. The basis of this approach is to develop the model for a hydrologically similar watershed where data are available, then to transfer the calibrated model to the watershed with the insufficient data. The criteria used to evaluate the similarity in hydrologic characteristics of the watershed include watershed physiographic characteristics (drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, land use/land cover) and mean annual precipitation.

Five stream flow gages were identified for potential use in the paired watershed approach: Wilson Creek, Tinker Creek, Crab Creek, Chestnut Creek, and Smith River. Upon reviewing the stations' period of records and the contributing drainage areas, and based on the hydrologic similarity between the watersheds (land use conditions, soil types, channel length and slope), it was determined that Tinker Creek could be used in the paired water approach.

Hourly precipitation, temperature, solar radiation, wind, and relative humidity data were obtained from the weather station at the Roanoke Regional Airport. After some initial model runs, it was evident that the Roanoke Regional Airport data could not adequately explain the observed stream flow at Tinker Creek near Daleville. There were significant discrepancies during some large storm events. Therefore, hourly precipitation data from the Covington Filter Plant, which is located on the other side of the watershed, was used to develop a synthetic precipitation time series representative of the Tinker Creek watershed. This precipitation data and other weather data were used as input in the Tinker Creek model. For the Mill Creek model and TMDL development, only the rainfall and climate data from the Roanoke Regional Airport were used in the model set-up.

The HSPEXP, an expert system software (Lumb and Kittle, 1993) was used in the HSPF model hydrologic calibration and validation. The selected calibration period was from September 1993 to August 1998. The period from October 1999 to September 2000 was used to validate the HSPF model. The validation results are presented in this report. The expert system calculates certain statistics; compares the model results with observed flow values; and provides guidance on parameter adjustment. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the Tinker Creek watershed. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Station 9-MLC005.44 has water quality data from 1988 to 2001 representing a total of 75 sampling events. The water quality data for this station was retrieved from STORET and DEQ and evaluated for potential use in the set-up, calibration, and validation of the water quality model. The period from January 1994 to December 1995 was used for the water quality calibration of the model and the period from January 1996 to December 1998 was used for the model validation

The existing fecal coliform loading was calculated based on the existing watershed conditions. The model input parameters reflect the conditions for the period from 1999 to 2000. The distribution of the existing fecal coliform load by source indicated that fecal coliform loading from pasture, cattle direct deposition, and wildlife direct deposition are the predominant sources of fecal coliform in the watershed.

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source allocation); and

MOS = margin of safety, 5% of TMDL.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was explicitly incorporated in this TMDL. Incorporating a MOS of 5% requires that allocation scenarios be designed to meet a 30-day fecal coliform geometric mean standard of 190 cfu/100 ml with 0% exceedance.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

For the hydrologic period from January 1995 to December 2000, the fecal coliform loading and the instream fecal coliform concentrations were estimated for the various scenarios using the developed HSPF model of the Mill Creek watershed. Based on load allocation scenario analysis, a TMDL allocation plan to meet the 30-day geometric mean water quality standard goal of 190 cfu/100 ml requires:

- 100 percent reduction of human sources of fecal coliform from failed septic systems and straight pipes;
- 100 percent reduction of the direct instream fecal coliform loading from livestock;
- 80 percent reduction of the fecal coliform loading from wildlife; and
- 20 percent reduction of the fecal coliform load from nonpoint sources.

A summary of the fecal coliform TMDL allocation plan loads for Mill Creek is presented in Table E-1.

Table E-1: Mill Creek TMDL Allocation Plan Loads (cfu/year)

Point Sources (WLA)	Nonpoint Sources (LA)	Margin of Safety (MOS)	TMDL
2.62E+11	4.18E+14	2.32E+12	4.22E+14

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

Section 303(d) of the Clean Water Act and current EPA regulations do not require the development of implementation strategies. However, including implementation plans as a TMDL requirement has been discussed for future federal regulations. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act directs DEQ in Section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters." The Water Quality Monitoring, Information and Restoration Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary, and the associated costs, benefits and environmental impacts of addressing the impairments. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

The development of the Mill Creek TMDL would not have been possible without public participation. The first public meeting was held in the Town of Riner on December 4, 2001 to discuss the process for TMDL development, source assessment input and bacterial source tracking data. Forty-three people attended this meeting. The second public meeting was held in the Town of Riner on February 19, 2002 to present the source assessment, preliminary bacterial source tracking results, and the hydrologic model calibrations. Twenty-two people attended. The third public meeting was held in the Town of Riner on March 26, 2002 to present the Draft TMDL. Forty-eight people attended. Copies of the presentation were available for public distribution. Meeting announcements were published in the Virginia Register. A public meeting notice newsletter was prepared by DEQ and mailed to county and city residents. Public meeting notices were published in The New River Current prior to the meetings.

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1.0 Introduction

1.1 Background

1.1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency (EPA)'s Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to better develop and regulate a more effective TMDL process. The role of DEQ is to act as a lead agency for the development of statewide TMDLs. DEQ focuses its efforts on all aspects of pollution reduction and prevention to the state waters. DEQ ensures compliance with the Clean Water Act and the Water Quality Planning Act, as well as encourages public participation throughout the TMDL development process. The role of DCR is to initiate nonpoint source pollution control programs on a state-wide level through the use of grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits from industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of contamination (DEQ, 2001a).

Since 1992 DEQ has developed a list, referred to as the 303(d) list, of impaired waters that details the pollutant(s) in violation and the potential source(s) of each pollutant (DEQ, 2001). The Water Quality, Monitoring, Information, and Restoration Act was passed in 1997 by the Virginia General Assembly to guide DEQ in creating and implementing TMDLs for the state waters on the 303(d) list (DEQ, 2001a). Virginia's 1998 303(d) report lists Mill Creek (ID# VAW-N21R) as impaired for fecal coliform.

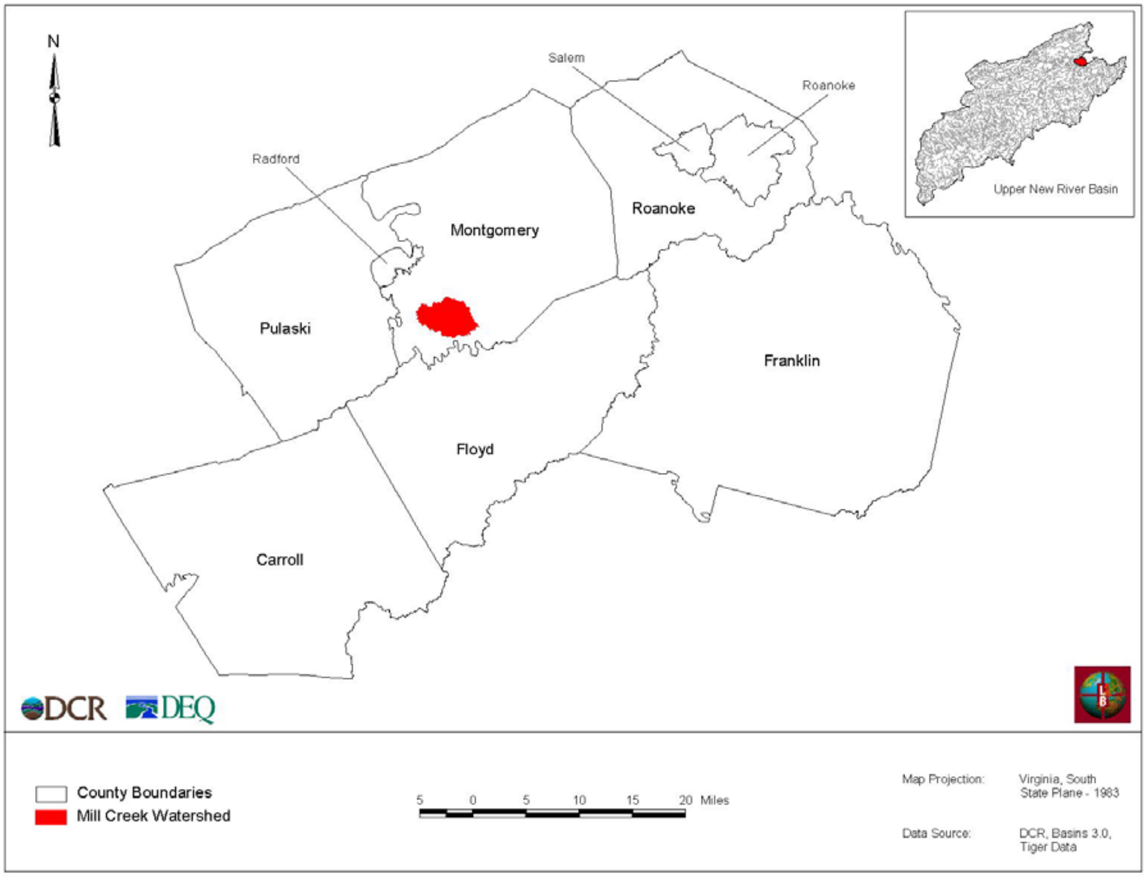
As required by the Clean Water Act and the Water Quality Planning and Management Regulations, once the TMDL has been developed, it should be distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Mill Creek was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform at two monitoring stations. Water quality monitoring samples from station 9-MLC005.44, which is located at the State Highway 8 (SH-8) (Fairview Church Road) bridge, failed to attain the primary contact designated use in 11 out of 18 samples. Water quality monitoring samples from station 9-MLC002.59, which is located at the SH-669 bridge, failed to meet the swimming goal in 3 out of 6 samples. Water quality monitoring sampling at station 9-MLC002.59 was discontinued in May 1994.

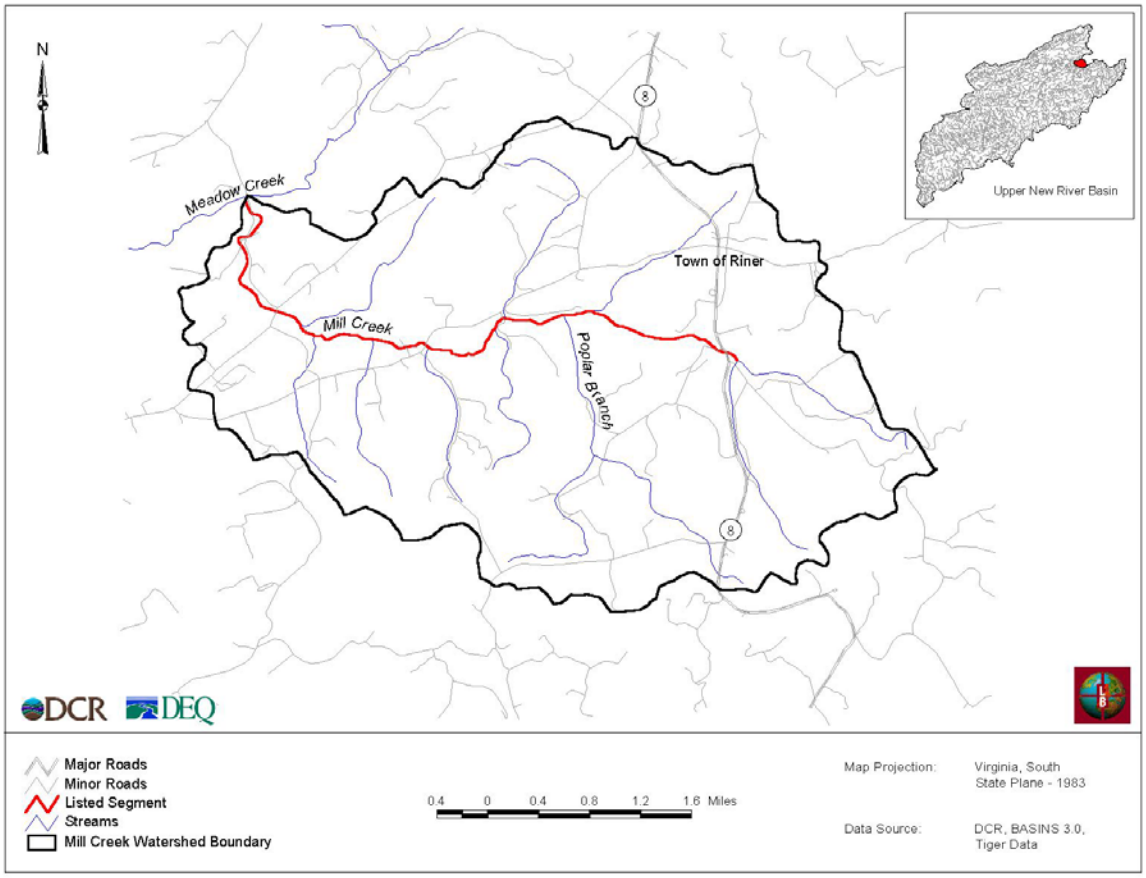
Mill Creek is located within the New River Basin, in the southwest portion of Virginia (Figure 1-1). The New River Basin is divided into two hydrologic units: Upper New - hydrologic unit code (HUC) 05050001 and Middle New - HUC 05050002. Mill Creek is located in the Upper New HUC. Mill Creek runs through Montgomery County, near the Town of Riner. It eventually drains into Meadow Creek, which is a tributary of the Little River.

Figure 1-1: Location of the Mill Creek Watershed



The Mill Creek impaired segment is 5.68 miles in length. The segment begins approximately 0.4 miles upstream of the Route 8 Bridge, south of the Town of Riner, and continues downstream to the confluence of Mill and Meadow Creeks. Figure 1-2 is a map showing the listed Mill Creek segment.

Figure 1-2: Mill Creek Watershed Listed Segment



1.3 Applicable Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

1.3.2 Applicable Water Quality Criteria

For a non-shellfish supporting waterbody to be in compliance with Virginia fecal coliform standards for contact recreational use, DEQ specifies the following criteria (9 VAC 25-260-170):

"…the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 mL at any time."

If the waterbody exceeds either criterion more than 10% of the time, the waterbody is classified as impaired and a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion is applied to a particular datum or data set (9 VAC 25-260-170). If the sampling frequency is one sample or less per 30 days, the instantaneous criterion is applied; for a higher sampling frequency, the geometric mean criterion is applied.

For Mill Creek, the TMDL is required to meet the geometric mean criterion since the computer simulation gives daily fecal coliform concentrations, analogous to daily sample collection. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

1.3.3 Water Quality Standards Review

Two regulatory actions related to the fecal coliform water quality standard are currently under way in Virginia. The first rulemaking pertains to the indicator species used to measure bacteria pollution. The second rulemaking is an evaluation of the designated uses as part of the state's triennial review of its water quality standards.

1.3.3.1 Indicator Species

EPA has recommended that all states adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters by 2003. EPA is pursuing the states' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and enterococci standard is scheduled for 2002 in Virginia.

1.3.3.2 Designated Uses

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard is described in 9 VAC 25-260-170 (see Section 1.3 of this report). This standard is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

In the TMDL public participation process, the residents in these watersheds often report that "people do not swim in this stream." It is apparent that many streams within the state are not used for primary contact recreation.

Recognizing that all waters in the Commonwealth are not used extensively for swimming, Virginia is considering re-designation of the swimming use for secondary contact in cases of: 1) natural contamination by wildlife, 2) small stream size, and 3) lack of accessibility to children, and because of widespread socio-economic impacts resulting from the cost of improving a stream to a "swimmable" status.

The re-designation of the current swimming use in a stream to a secondary use will require the completion of a Use Attainability Analysis (UAA). A UAA is a structured, scientific assessment of the factors affecting the attainment of the use and may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, the Commonwealth, and EPA will have an opportunity to comment on these special studies.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

Mill Creek, in Montgomery County Virginia, was placed on the 1998 303(d) list for violations of the fecal coliform standards for contact recreation uses. The TMDL focuses on 5.68 miles of the creek starting at approximately 0.4 miles upstream of the Route 8 Bridge, south of the Town of Riner, to the confluence with Meadow Creek.

One of the first steps in developing TMDLs is determining the numeric endpoints, or water quality goals/targets, for each waterbody. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Mill Creek TMDL are established in the Virginia Water Quality Standards (9 VAC 25-260-20), which states that all waters in the state should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore the current water quality target for Mill Creek, as stated in 9 VAC 25-260-170 (Section 1.3 of this report), is a fecal coliform count where the geometric mean is not greater than 200 counts per 100 ml for two or more water quality samples taken in a 30-day period.

2.2 The Critical Condition

The critical condition is considered the “worst case scenario” of environmental conditions in Mill Creek. If the TMDL is developed such that the water quality targets are met under the critical condition, then the water quality targets would be met under all other conditions.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Mill Creek is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

Mill Creek flows through a predominantly rural setting; however, there are built-up areas located in several areas throughout the watershed. The majority of the built-up areas are near the Town of Riner. Run-off from livestock grazing, manure applications, industrial processes, and residential waste can contribute to increased levels of bacteria in the surface waters. Since the Mill Creek watershed has both rural and built-up areas, the critical condition will need to consider the location of large outfalls and contributions made from those outfalls during dry conditions when there is little stream flow and dilution of bacteria. If there are no significant dry weather flows (contributions from the outfalls) then the levels of fecal coliform may be attributed to direct deposition from livestock and wildlife.

Because fecal coliform loadings result from sources that can contribute during wet weather and dry weather, a critical condition cannot be determined from the available water quality data. Review of the available water quality data for Mill Creek indicated that violation of the 200 cfu/100ml standard occurred during all months of the year. Instead the fecal coliform loading from direct (or point) sources and nonpoint sources and the in-stream water quality conditions of Mill Creek response were considered under various hydrological conditions. These would include typical or average, wet and dry hydrological conditions. The model was run under these various hydrological conditions to account for wet weather and dry weather periods. The model demonstrated that the geometric mean standard violations were occurring predominantly under low flow periods. Therefore, based on the model results, the low flow periods were considered the critical condition and direct sources, which dominate under such hydrologic conditions, have to be reduced in order to meet the geometric mean standard.

2.3 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality as a result of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed the consideration of temporal variability in fecal coliform loading within the watershed.

3.0 Watershed Description and Sources Assessment

In this section, the types of data available and information collected for the development of the Mill Creek TMDL are presented. This information was used to characterize Mill Creek and its watershed and to inventory and characterize the potential point and nonpoint sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Watershed physiographic data that describe the watershed physical conditions such as the topography, soils, and land use;
(2) Hydrographic data that describe the stream physical conditions, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation;
(3) Data and information related to the use and activities in the watershed that can be used in the identification of potential fecal coliform sources; and
(4) Environmental monitoring data that describe the stream flow and the water quality conditions in the stream.

Table 3-1 shows the various data types and the data sources used in the Mill Creek TMDL.

Table 3-1: Inventory of Data and Information Used in the Mill Creek TMDL Development

Data Category	Description	Potential Source(s)
Watershed physiographic data	Watershed boundary	USGS, DCR
	Land use/land cover	DCR
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS; DCR; Field
	Stream morphology	
Weather data	Hourly meteorological conditions	Roanoke Airport, NCDC, Earth Info
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	State, county, and city governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR nutrient management specialist, Skyline SWCD, NRCS
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	New River Health District, Montgomery County Public Sewer Authority, U.S. Census Bureau
	Straight pipes	DEQ
	Best management practices (BMPs)	DCR, NRCS, Skyline SWCD
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMR)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient instream monitoring data	DEQ
	Stream flow data	USGS, DEQ

Notes
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NRCS: Natural Resources Conservation Service
SWCD: Soil and Water Conservation District
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

3.2.1 Watershed Boundaries

Mill Creek is a tributary of the New River as part of the New River Basin. The Mill Creek watershed is approximately 9,308 acres or 14.54 square miles. The watershed is located in southwestern section of Montgomery County and makes up about 4 percent of the county's land area. State Highway 8 (SH-8) runs through the western section of the watershed in a southerly direction. SH-8 connects the Town of Riner, which is located in the Mill Creek watershed, to Interstate 81 (I-81).

3.2.2 Topography

The digital elevation model (DEM) and the USGS 7.5 minute quadrangle maps were used to characterize the topography in the watershed. The DEM data was obtained from BASINS and compared to the Riner and Radford South, Virginia USGS 7.5 minute quadrangle maps. The elevation in the watershed ranged from 1,000 to 2,760 feet above mean sea level.

3.2.3 Soils

The Mill Creek watershed soil characterization was based on the Soils Survey of Montgomery County (SCS, 1985). The majority of the soils in the watershed are comprised of the Berks-Groseclose-Lowell soils mapping units with minor portions of Berks-Lowell-Raynes soils. Theses soils mapping units are moderately deep and deep, well drained, gently sloping to very steep soils that have loamy and clayey subsoil and formed in shale, limestone, and sandstone residuum; on moderately dissected uplands. The distribution of the soils in the Mill creek watershed is presented in Table 3-2.

Table 3-2: Soil Types and Characteristics in the Mill Creek Watershed

Map Unit ID	Soil Association	Percent
3D, 3E	Berks-Lowell-Rayne	15
2B, 2C	Berks-Groseclose-Lowell;	85

Source: NRCS, 2000

The hydrologic groups represent different levels of infiltration capacity of the soils. A designates soils that are well to excessively well-drained, whereas D designates soils that are poorly drained. This means that soils in hydrologic group A allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group A, soils in hydrologic group D allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in Table 3-3.

Table 3-3: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well-drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to Slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover

For the soil series present in the watershed, two hydrologic groups—B and C—may exist within the Berks-Groseclose-Lowell and Berks-Lowell-Rayne mapping units. Based on the published soil survey (1985), it was determined that a C hydrologic group designation would be representative of the infiltration capacity of the soils in the Mill Creek watershed.

3.2.4 Land Use

Land use characterization was based on GIS data provided by DCR for the Mill Creek watershed. DCR developed this digital land use/land cover data using satellite images, digital ortho quarter quads (DOQQ) and extensive ground truthing. The land uses that are present in Mill Creek are presented in Table 3-4, which shows the land use distribution in the watershed by area and percentage. The table shows that dominant land uses in the watershed are improved pasture, forest, and crop land. The improved pasture accounts for 61% of the watershed land area. Forest land accounts for 22% of the watershed. Crop land accounts for 10% of the watershed. The combination of these three land uses account for 93% of the land area of the watershed. Brief descriptions of the land use types are presented in Table 3-5.

Table 3-4: Land Use Distribution in Mill Creek Watershed

Land Use Category	Land Use Type	Acres	Percent of Watershed's Land Area
Residential	Mobile Home Park	8.98	0.10
	Medium Density Residential	107.51	1.16
	Low Density Residential	176.22	1.89
Urban	Mixed Urban or Built-up Land	3.71	0.04
	Transportation	23.02	0.25
	Industrial	14.79	0.16
	Commercial & Services	63.07	0.68
	Open Urban Land	46.23	0.50
	Barren	38.74	0.42
Agriculture	Crop Land	959.10	10.31
	Improved Pasture	5,630.97	60.50
	Unimproved Pasture	68.23	0.73
	Grazed Woodland	8.62	0.09
	Farmstead	112.73	1.21
Forest	Forested	2,035.55	21.87
Other	Water	6.18	0.07
	Wetlands	3.35	0.04
Total		**9,307.86**	**100.00**

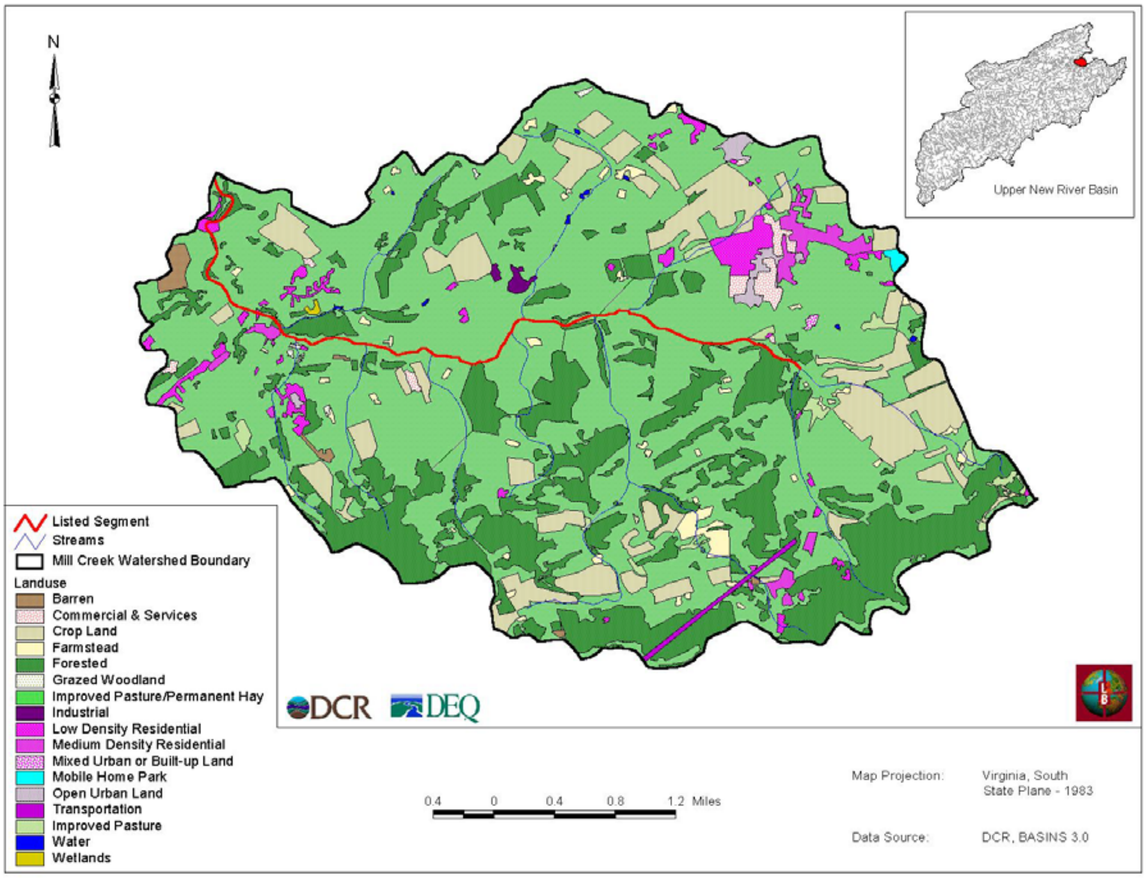
Table 3-5: Descriptions of Land Use Types

Land Use Type	Description
Barren	All types of barren land, including rock, beaches, strip mines, and bare transition areas, but not non-vegetated wetlands.
Commercial/ Services	Retail trade areas, wholesale service areas, and institutions. Includes all associated properties, such as yards and parking lots. Institutional land consists of educational, military, corrections, medical, religious, and government facilities.
Crop Land	All types of crop land except rotational hay.
Farmstead	Farm building “complexes”, isolated farm buildings, storage sheds, and farm based residences. May include small diary animal waste containment facilities but not those large enough to be easily identified with 5m imagery.
Forest	All types of forest lands except those which have been harvested, those which are routinely grazed by farm animals, and those which are classified as forested wetlands.
Grazed Woodland	Wooded areas (> 50% canopy) that appear to allow livestock access.
Improved Pasture	Pasture is good to very good coverage. May include “older” hayfields that are likely part of a less extensive row crop-hay rotation.
Industry	Manufacturing and industrial parks, including associated areas such as storage yards, parking lots, and tanks.
Low Density Residential	Detached single family/duplex dwelling units and their associated areas, such as yards, sheds, except those in large mostly wooded lots. Densities of .2 dwelling units/acre to 2 dwelling units/acre.
Medium Density Residential	Detached single family/duplex dwelling units, row housing, and their associated areas. Densities of 2 dwelling units/acre to 8 dwelling units/acre.
Mixed Urban or Built Up Land	Areas of mixed urban development other than mixed described as industrial/commercial complex mix, such as sites undergoing construction activity or some other type of urban transition.
Mobile Home Park	Mobile home and trailer parks. Trailers not in a mobile park are coded in accordance to the residential density as per above.
Open Urban Land	Urban areas not requiring structures and areas characterized by open land, particularly such lands within an urbanized area. Includes golf courses (but not rural golf courses), zoos, cemeteries, city parks, fair grounds, landfills, and other generally undeveloped urban uses dominated by porous surface areas.
Transportation	Lands occupied by transportation such as airports, rail lines and yards, highways, and shipping ports. Also, communication uses such as towers and large satellite dishes, and utility uses such as electric, gas, water, and wastewater facilities.
Unimproved Pasture	Pasture land that appears to be less intensively managed in terms of brush/weed control, fertilizer applications, constructed water supplies and rotational grazing.
Water	All types of water features except those considered wetlands.
Wetlands	All types of wetlands, including forested wetlands and non-vegetated wetlands. Any wetland so identified in the National Wetland Inventory (NWI), but not the deepwater habitats of the NWI.

Source: DCR.

Figure 3-1 is a map showing the land use distribution in the watershed. Improved pasture and crop land uses are relatively evenly dispersed throughout the watershed. Forest land is most predominant in the southern section of the watershed, specifically along the watershed boundary. Urban and residential areas occurring in the watershed are primarily associated with the Town of Riner.

Figure 3-1: Land Use in the Mill Creek Watershed



3.3 Stream Flow Data

Stream flow data for Mill Creek do not exist; therefore the paired-watershed approach was used to set up and calibrate the HSPF model. The basis of this approach is to develop the model for a hydrologically similar watershed where data are available, then to transfer the calibrated model to the watershed with the insufficient data. The criteria used to evaluate the similarity in hydrologic characteristics of the watershed include watershed physiographic characteristics (drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, land use/land cover) and mean annual precipitation.

Five streams, each with a stream flow gaging station, were identified for potential use in the paired watershed approach. These streams are: Wilson Creek, Tinker Creek, Crab Creek, Chestnut Creek, and Smith River. Upon reviewing the stations' period of records and the contributing drainage area, it was determined that only Tinker Creek and Chestnut Creek flow gages could be used in the paired water approach.

Using the criteria mentioned above, Tinker Creek, located within the Upper Roanoke River Basin, was chosen because it is more hydrologically and physiographically representative of Mill Creek than Chestnut Creek is. The flow monitoring station for Tinker Creek (02055100) is located near Dalesville, Virginia. The Tinker Creek flow data was retrieved for the period from 1956 to 2000 from the USGS and used in the model set-up and in hydrological calibration and validation of the model. The calibrated model was then transferred to the Mill Creek watershed.

A detailed discussion of the paired watershed approach and a presentation of the similarities between Tinker and Mill Creek are presented in Section 4.

3.4 Instream Water Quality Conditions

Water quality data for the Mill Creek watershed was obtained from DEQ, which conducted sampling at nine water quality monitoring stations located within the boundary of Mill Creek watershed. The stations' locations are summarized in Table 3-6. Stations 1 through 6 are located on the mainstem of Mill Creek, stations 7 and 8 are located on two unnamed tributaries of Mill Creek, and station 9 is located on Meadow Creek. Table 3-7 lists the water quality sampling period of record, the number of samples collected, the minimum and the maximum observed concentrations, and the percent violation of the water quality standard. Figure 3-2 is a map showing the locations of these in-stream water quality monitoring stations.

Table 3-6: In-stream Water Quality Monitoring Stations Located in the Mill Creek Watershed

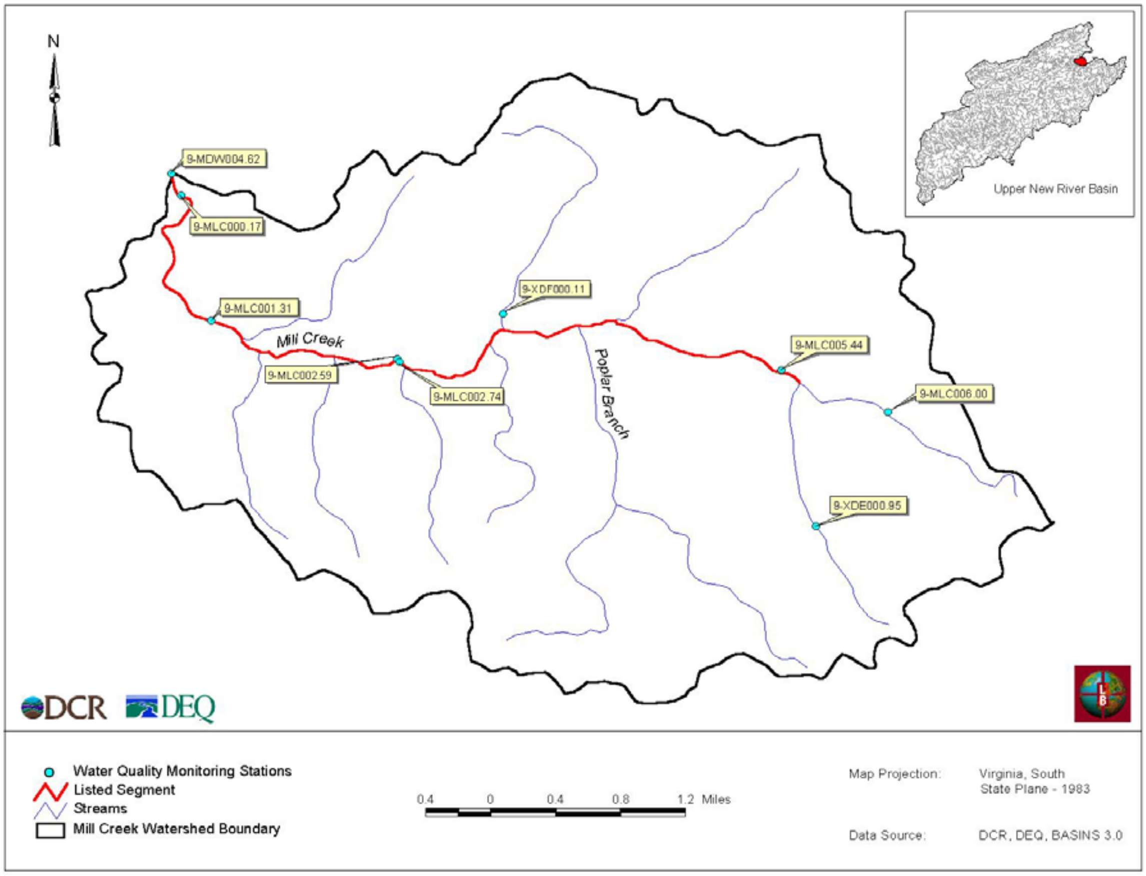
No.	Station Id	Station Location	Stream Name	River Mile
1	9-MLC000.17	Rt. 600 Bridge	Mill Creek	0.17
2	9-MLC001.31	Rt. 693 Bridge	Mill Creek	1.31
3	9-MLC002.59	Route 669 Bridge - below Riner STP	Mill Creek	2.59
4	9-MLC002.74	Private Road off Rt. 616	Mill Creek	2.74
5	9-MLC005.44	Route 8 Bridge - above Riner STP	Mill Creek	5.44
6	9-MLC006.00	Private Road off Rt. 616	Mill Creek	6
7	9-XDE000.95	Rt. 678 Bridge	Mill Creek, Unnamed Tributary	0.95
8	9-XDF000.11	Private Road off Rt. 669	Mill Creek, Unnamed Tributary	0.11
9	9-MDW004.62	Rt. 600 Bridge	Meadow Creek	4.62

Table 3-7: Summary of Water Quality Sampling Conducted in the Mill Creek Watershed

No.	Station Id	Period of Record	Number of Samples	Minimum (cfu/100ml)	Maximum[1] (cfu/100ml)	Violation[2] (%)
1	9-MLC000.17	1999-2001	5	100	3,900	60
2	9-MLC001.31	1999-2000	5	200	700	100
3	9-MLC002.59	1988-1994	22	51	8,000	55
4	9-MLC002.74	1999-2002	10	400	3,000	70
5	9-MLC005.44	1988-2002	58	100	8,000	47
6	9-MLC006.00	1999-2000	5	100	8,000	60
7	9-XDE000.95	1999-2000	5	100	8,000	100
8	9-XDF000.11	1999-2000	5	400	2,600	100
9	9-MDW004.62	1999	4	250	2,000	75

1: Samples were censured at 8,000 cfu/100ml.
2: The percent violation was calculated based on the geometric mean standard for samples collected within a 30-day period. The instantaneous standard was used when the sampling frequency was more than 30 days.

Figure 3-2: Mill Creek Watershed Water Quality Monitoring Stations



Station 9-MLC000.17 is the most downstream station and station 9-MLC006.00 is the most upstream station located on Mill Creek. The water quality data for these two stations as well as other stations in between indicate that the violation of the fecal coliform standard ranged from 47 to 100%.

3.4.1 Bacteria Source Tracking

As part of the Mill Creek TMDL development, DCR provided Bacteria Source Tracking (BST) data related to in-stream sampling and analysis of fecal bacteria. The objective of BST is to identify the sources of fecal coliform in the listed segment of Mill Creek. Subsequently, this information was used in the model set-up and in the distribution of the fecal coliform loading among the various sources, such as human, livestock, and wildlife.

There are various methods of performing BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are all referred to as "DNA fingerprinting" and are based on the unique genetic makeup of different strains, or subspecies, of fecal bacteria. Biochemical (phenotype) methods are based on an effect of an organism's genes that actively produce a biochemical substance. The type and quantity of these substances produced are what are actually measured. Chemical methods are based on finding chemical compounds that are associated with human wastewaters and would be restricted to determining sources of pollution as human or non-human.

For the Mill Creek TMDL, the Antibiotic Resistance Analysis (ARA) method of BST was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. ARA offers low cost per sample, fast turnaround times for analyzing samples, and can be performed on large numbers of isolates; typically, 48 isolates per unknown source such as in-stream water quality sample.

In the Mill Creek watershed, two sampling stations were set up and water quality samples for BST were collected and analyzed on a monthly basis from January 2001 through December 2001. One station was located at the Mill Creek mouth on Meadow Creek, which is the end of the Mill Creek listed segment. The second station was located at the confluence of Mill Creek and Poplar Branch. Figure 3-3 is a map showing the locations of the sampling stations on Mill Creek.

Three categories of fecal bacteria sources were considered: human, wildlife, and livestock. The BST results for 12 sampling events on a monthly basis at two stations located on Mill Creek are presented in Table 3-8. The data indicate that fecal coliform bacteria from human, wildlife, and livestock were present in Mill Creek. The human signature ranged from 0 to 38%, the wildlife signature ranged from 0 to 67%, and the livestock signature ranged from 27 to 100%.

Figure 3-3: Mill Creek Watershed Bacteria Source Tracking Sampling Stations

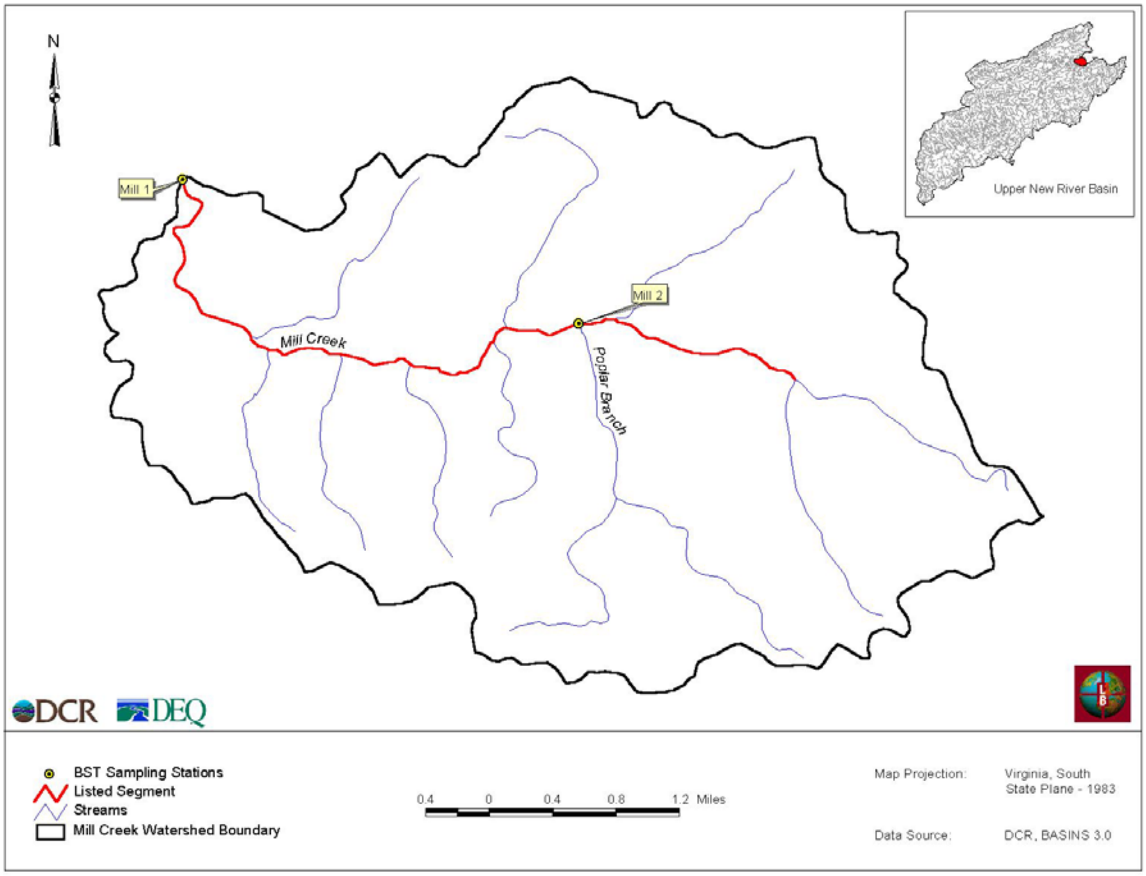


Table 3-8: Results of BST Analysis Conducted in the Mill Creek Watershed

Location	Date	Fecal Coliform cfu/100ml	Percent of Enterococci Classified as		
			Wildlife	Human	Livestock
Mill 1	1/10/01	65	67%	0%	33%
	2/15/01	70	27%	19%	54%
	3/20/01	70	33%	13%	54%
	4/28/01	2,100	50%	0%	50%
	5/8/01	1,740	38%	2%	60%
	6/11/01	490	4%	8%	88%
	7/19/01	1,040	0%	0%	100%
	8/14/01	360	43%	7%	50%
	9/21/01	460	37.5%	0%	62.5%
	10/6/01	380	35%	38%	27%
	11/6/01	60	52%	0%	48%
	12/11/01	1,056	36%	13%	51%
Mill 2	1/10/01	50	58%	0%	42%
	2/15/01	90	17%	6%	77%
	3/20/01	70	18%	2%	80%
	4/28/01	290	26%	0%	74%
	5/8/01	1,490	13%	4%	83%
	6/11/01	740	6%	2%	92%
	7/19/01	2,850	8%	2%	90%
	8/14/01	1,040	6%	0%	94%
	9/21/01	130	8%	0%	92%
	10/6/01	240	29%	0%	71%
	11/6/01	690	13%	4%	83%
	12/11/01	2,784	15%	2%	83%

3.5 Fecal Coliform Sources Assessment

This section will focus on characterizing the fecal coliform sources in the watershed that potentially contribute to the fecal coliform loading to Mill Creek. These sources include permitted facilities, sanitary sewer systems and septic systems, livestock, land application of manure and biosolids wildlife, and pets. Section 4 will include a detailed presentation of how these sources are incorporated and represented in the model.

3.5.1 Permitted Facilities

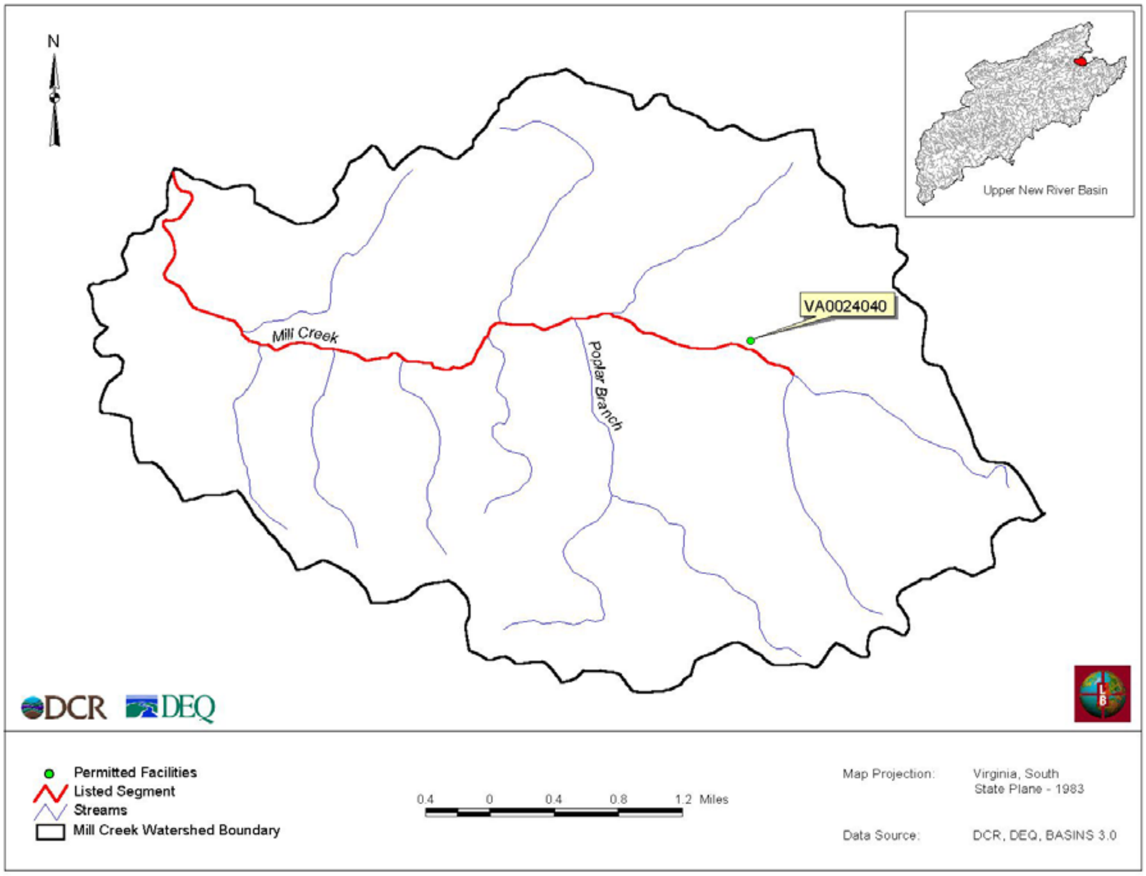
There is only one permitted facility located in the Mill Creek watershed based on data and information obtained from DEQ's West Central Regional Office. The Riner Sewage Treatment Plant (STP) permit number, design flow, and status are presented in Table 3-9. The location of the plant is presented in Figure 3-4.

Table 3-9: Permitted Discharge in the Mill Creek Watershed

Permit Number	Facility Name	Design Flow (gpd)[1]	Status
VA0024040	Riner STP	100,000	Active

1. gpd: gallons per day

Figure 3-4: Location of Permitted Facility



The available flow and fecal coliform data for the Riner STP were retrieved and analyzed. Instantaneous flow data were available for September 2000 to October 2001, and the average daily flow data were available for January 1998 to July 2001. The maximum daily flow ranged from 14,000 to 51,000 gallons per day (gpd) (0.014 to 0.051 million gallons per day (MGD) and the average monthly flow ranged from 4,300 to 37,000 gpd (0.0043 to 0.037 MGD). Figures 3-5 and 3-6 show the variation of the Riner STP flow for the two periods. For the TMDL development, a flow of 10,000 gpd was considered representative of the Riner STP flow conditions. This flow was used in the HSPF model set-up and calibration.

Figure 3-5: Riner STP Instantaneous Flow

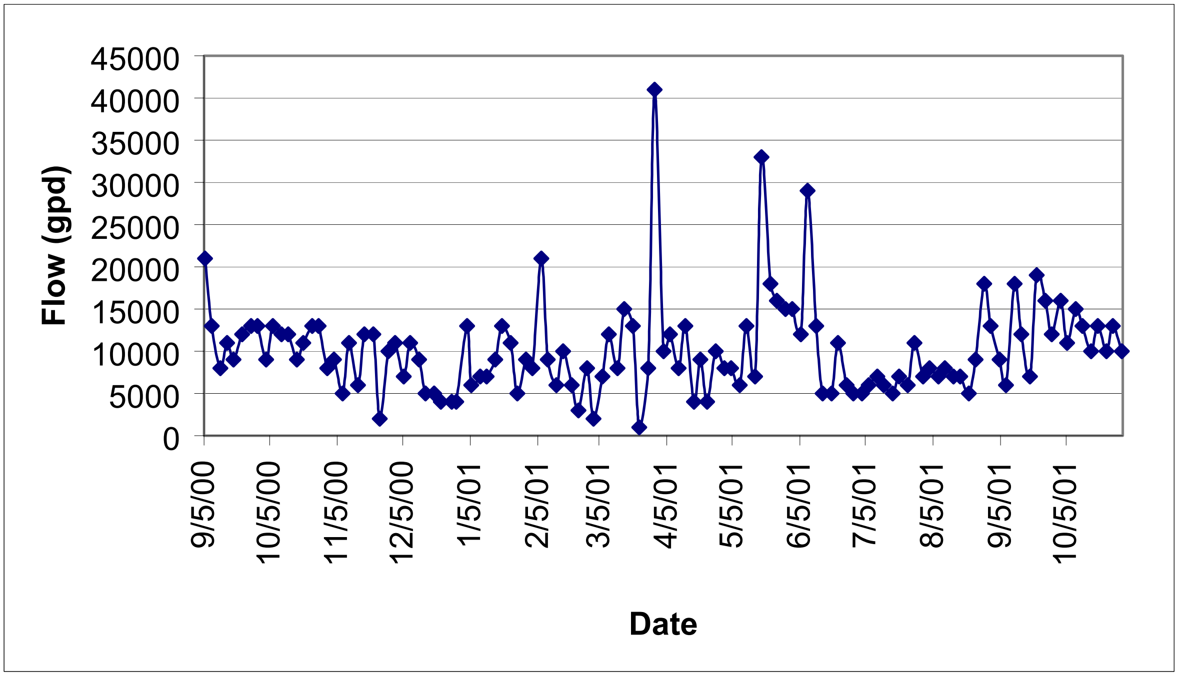
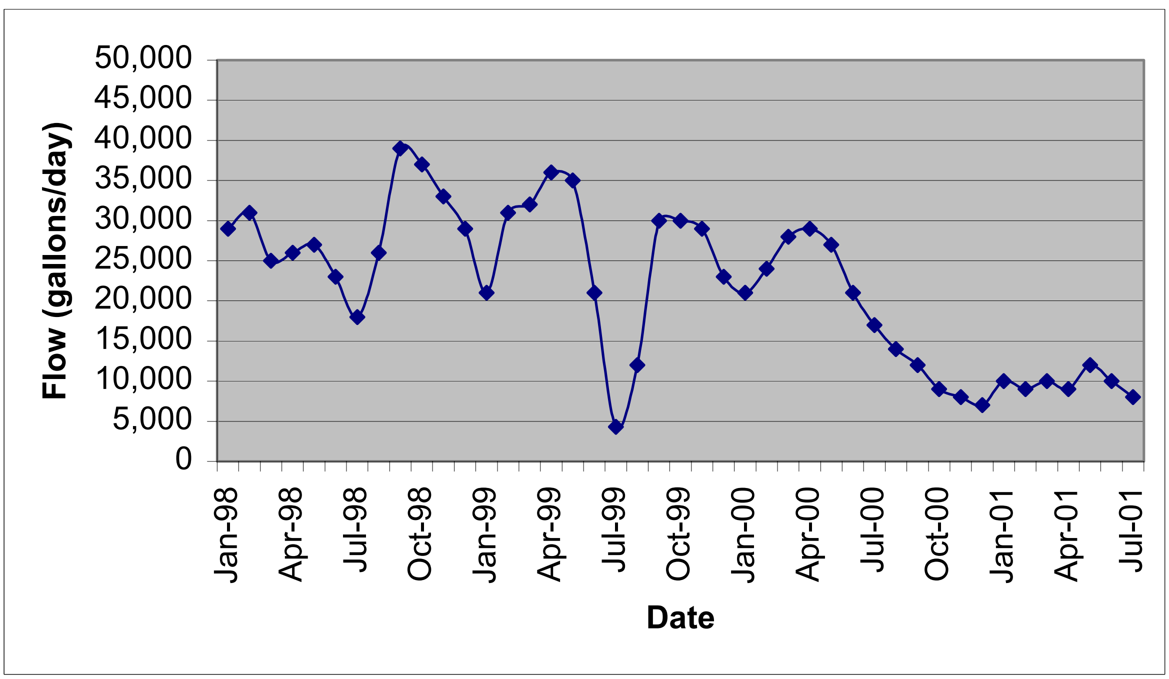
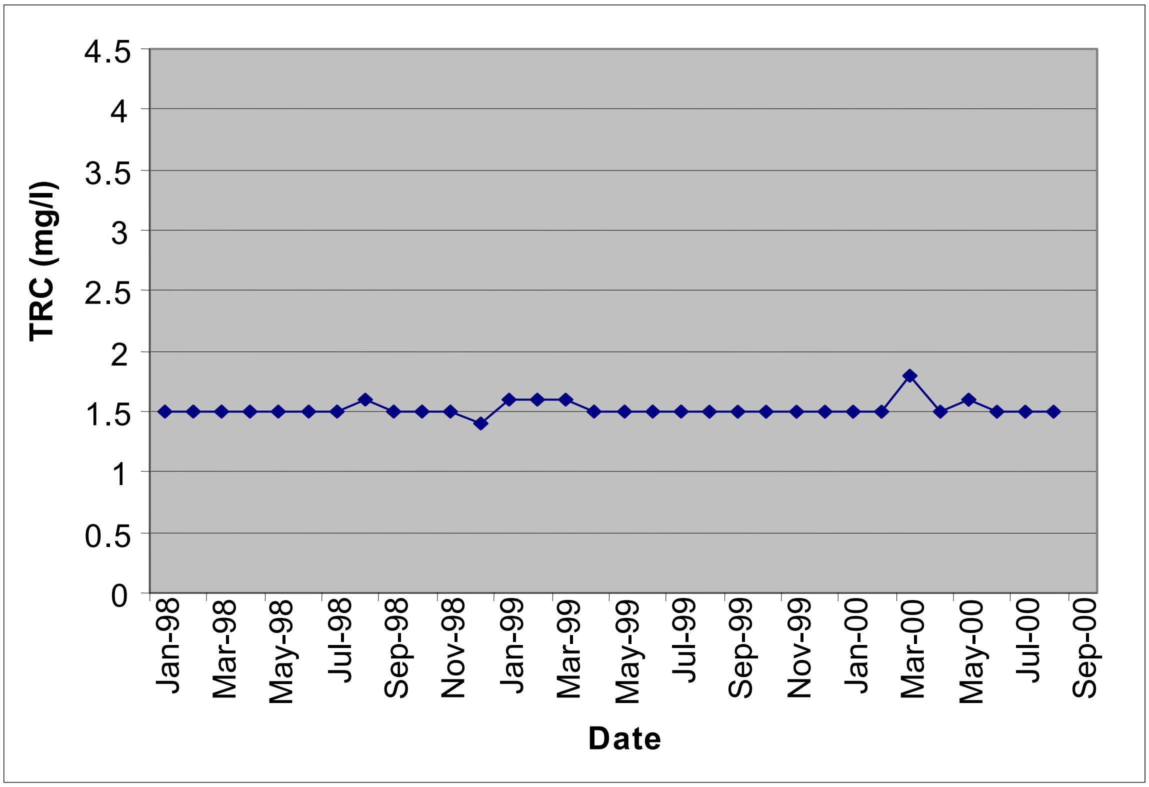


Figure 3-6: Riner STP Average Monthly Flow



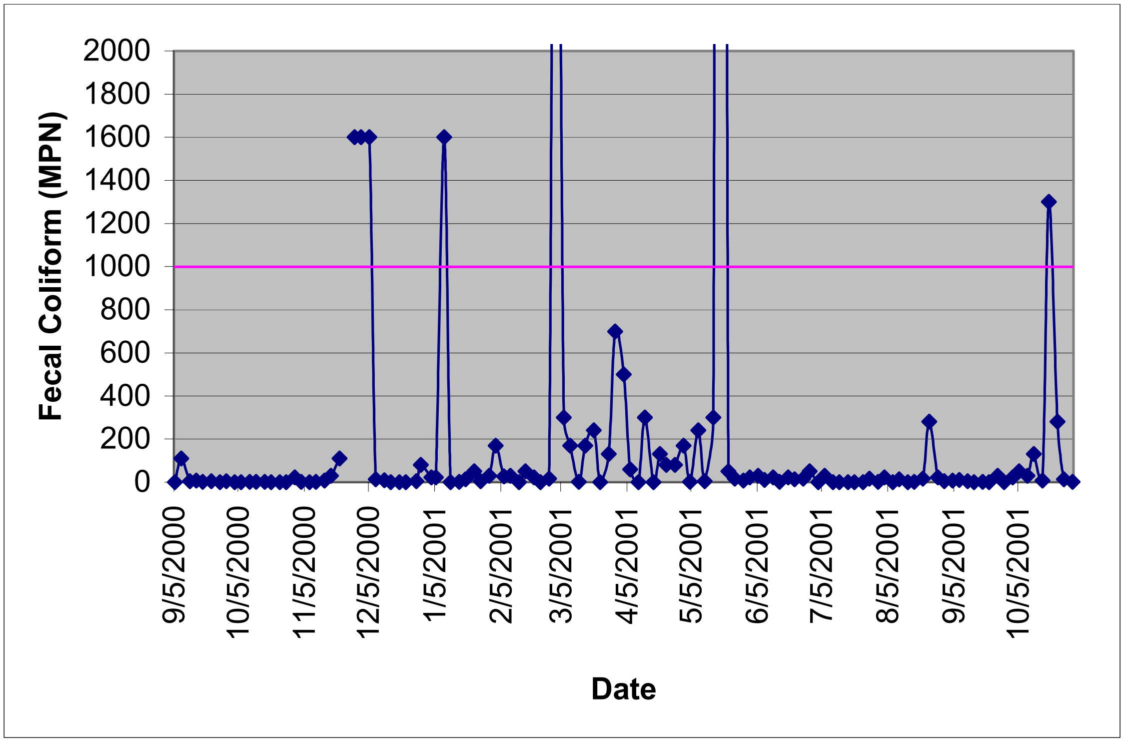
The Riner STP switched from using chlorine to ultraviolet for disinfection in September 2000. Prior to this switch, the Riner STP reported the residual chlorine concentration levels; these are presented in Figure 3-7. Chlorine concentration data for the period from January 1998 to August 2000 indicate that total residual chlorine (TRC) concentrations ranged from 1.4 to 1.8 mg/l. This indicates that adequate disinfection was achieved at the plant.

Figure 3-7: Riner STP TRC Concentration



Fecal coliform concentration data were available for the period from September 2000 to October 2001. Figure 3-8 shows the variation of the fecal coliform concentration in the plant effluent. The fecal coliform concentrations ranged from 0 to 16,000 most probable number (MPN). Although the daily values exceeded the 1,000 cfu/100 ml standard on seven occasions, no permit limit violation occurred during this reporting period based on the geometric mean standard of 200 cfu/100ml. For the Mill Creek TMDL development, the 30-day geometric mean 200 cfu/100 ml concentration standard was used in the HSPF model, not the instantaneous 1,000 cfu/100 ml standard.

Figure 3-8: Riner STP Fecal Coliform Concentration

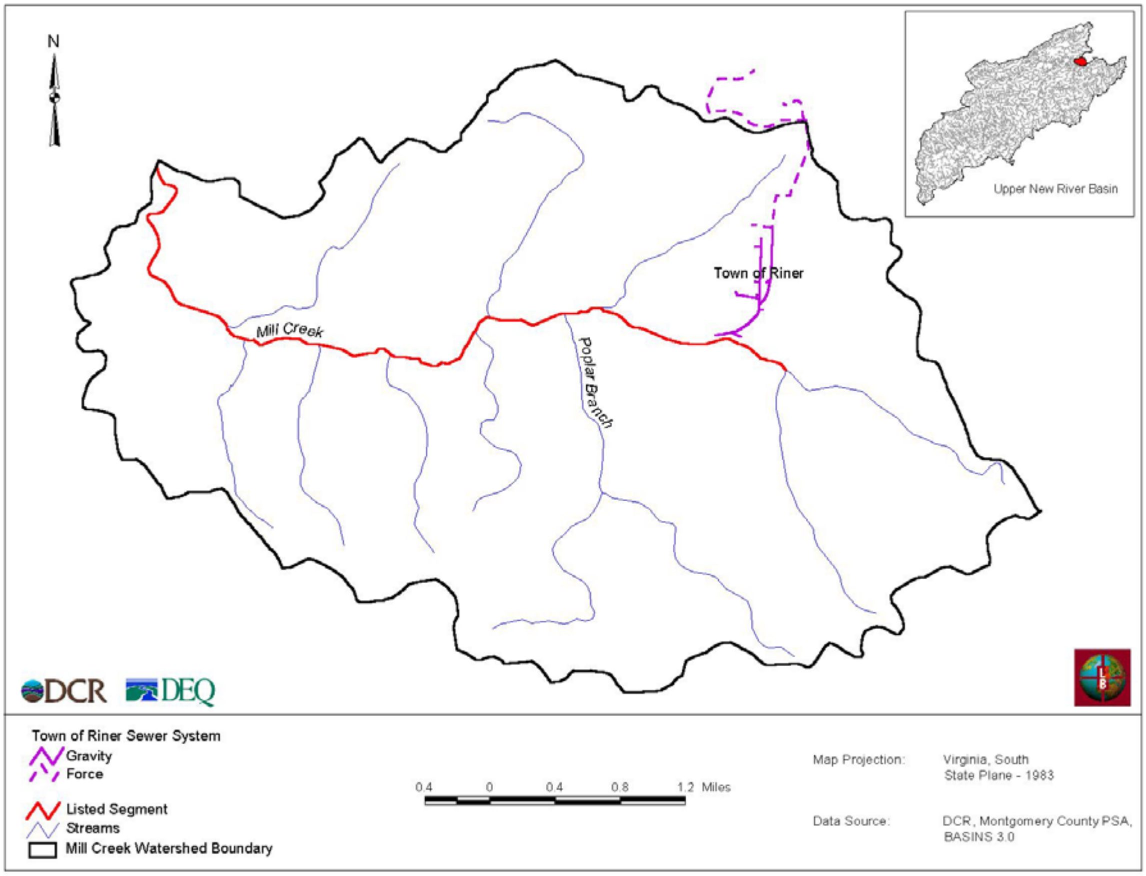


3.5.2 Extent of Sanitary Sewer Network

The extent of the sanitary sewer network was determined from maps provided by the Montgomery County Public Sewer Authority (Mabry, Per. Comm., October 29, 2001). The extent of the sewer system in the Mill Creek watershed is presented in Figure 3-9. The sewage collected in this network is conveyed to the sewer treatment plant located in the southern section of the Town of Riner. The housing units that are not served by a public sewer rely on septic systems for the treatment of household waste.

Estimates of the total number of households connected to the sewer system are presented in the next section.

Figure 3-9: Sewer Areas in Mill Creek Watershed



3.5.3 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems were based on four sources of data:

- USGS 7.5 minute quadrangle maps,
- Montgomery County tax parcel data,
- Montgomery County Public Sewer Authority maps, and
- U.S. Census Bureau data.

The Riner and the Radford South USGS 7.5 minute quadrangle maps were combined and used to create a single map that covers the entire Mill Creek watershed. The housing units on the USGS maps were digitized and converted to a GIS layer of the total housing units in the watershed. After combining the housing units GIS layer with the map of the sewer network in the watershed, it was determined that there is a total of 563 housing units in the watershed. In addition, 72 of these households are sewered and the remaining 491 are on septic systems. Since the USGS map is dated 1978, the 491 septic systems are at least 23 years old.

Based on the tax parcel data obtained from Montgomery County, the total number of addressable structures in the watershed is 645, which reflects a 13% increase from the 1978 data from the USGS maps. An addressable structure is a structure with a U.S. Postal Service address. Combining the tax parcel data with the sewer network maps indicated that there are 79 sewered housing units and 566 housing units on septic systems.

The U.S. Census Bureau 2000 data for Montgomery County was reviewed to establish the population growth rate in the county and to validate the housing unit calculation. Summary of the census data indicates the following:

- In 2000 the population was 83,629;
- Number of households is 30,997;
- Total number of housing units is 32,527;
- Population density is 215.5 persons per square mile; and
- Household density is 2.40 persons per household.

The total number of housing units in the watershed was calculated based on the above Census data for Montgomery County. Taking into account that the watershed makes up about 3.8% of the County land area and that 61% of the watershed is pastureland, the total number of housing units was estimated at 482. This assumes that there are no homes on the improved pasture lands, which is not true in some cases. Therefore, number of housing units estimated based on the tax parcel data is more representative of the conditions in the watershed and was used in the TMDL development.

The Census data also indicated that the population growth between 1980 and 1990 was 16.4% and between 1990 and 2000 was 13%. For this TMDL development, a 13% population increase over the next 10 years was considered to be representative of future population growth in the watershed.

3.5.3.1 Failed Septic Systems

To determine the amount of fecal coliform contributed by human source, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rates were determined based on the total amount of septic systems versus the number of applications for new systems and the number of repairs to existing systems in Montgomery County. Table 3-10 shows the number of applications for new systems as well as the number of repairs over the last five years in Montgomery County. This data was combined with the population data to establish the rate of applications for new septic systems and the rate of repair of existing septic systems in the watershed. Table 3-11 shows the rate of applications for new septic systems in Montgomery County ranged from 1.3 to 2.1% from 1997 to 2001. For the same period, the data indicate that the rate of septic system repair permits ranged from 0.10 to 0.17%. These septic system failure rates are considered low for an area where many septic systems have been operating for over 23 years. This low rate may be attributed to a large number of septic system repairs being performed without obtaining a permit.

Table 3-10: Number of Applications for New Septic Systems and Number of Repairs in Montgomery County (including outside the Mill Creek Watershed)

Year	Applications for New Septic Systems	Repairs of Existing Systems
1997	659	54
1998	708	43
1999	644	33
2000	477	44
2001	466	56
Average	**591**	**46**

Source: Marcussen, Per. Comm., December 1, 2001.

Table 3-11: Rates of Applications for New Septic Systems and Rates of Repairs in Montgomery County (including outside the Mill Creek Watershed)

Year	Total Households in Montgomery County*	% New	% Repair
1997	32,681	2.0	0.17
1998	33,419	2.1	0.13
1999	34,174	1.9	0.10
2000	34,845	1.4	0.13
2001	35,633	1.3	0.16

*Calculations based on 2.4 persons per household

A detailed discussion of the failure rates, flow, and fecal coliform concentration is presented in Section 4.

3.5.4 Livestock

An inventory of the livestock residing in the Mill Creek watershed was conducted using data and information provided from the DCR nutrient management specialist, Skyline Soil and Water Conservation District, Natural Resources Conservation Service (NRCS), and field surveys. The data and information indicate the following:

- five dairy operations exist in the watershed,
- beef cattle operations exist throughout the watershed,
- no poultry operations exist in the watershed,
- no swine operations exist in the watershed, and
- other livestock includes horses and sheep.

Table 3-12 summarizes the livestock inventory in the watershed.

Table 3-12: Mill Creek Watershed Livestock Inventory

Livestock Type	Total Number of Animals
Beef Cattle	2,850
Dairy Cattle (total*)	950
Chicken	0
Swine	0
Horse	34
Goat	0
Sheep	250

*includes milked, dry cows and replacement heifers
Sources: DCR, Skyline Soil & Water Conservation District, field surveys, Mill Creek stakeholders

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. Table 3-13 shows the average fecal coliform production per animal per day contributed by each type of livestock.

Table 3-13: Daily Fecal Coliform Production of Livestock

Source	Daily Fecal Production (in millions of cfu/day)
Beef Cattle	33,000
Dairy Cattle: Milked or Dry Cow	25,200
Dairy Cattle: Heifer	11,592
Horse	420
Goat	27,000
Sheep	27,000

Sources: ASAE, 1998; Metcalf and Eddy, 1979; Map Tech, Inc., 2000; EPA, 2001.

The impact of fecal coliform loading from livestock depends on whether the loading is directly deposited in the stream or indirectly deposited in the stream via runoff. For this TMDL, the fecal coliform deposited while in confinement and while grazing was considered indirect and the fecal coliform deposited when livestock directly defecate in the stream was considered direct. The distribution of the daily fecal coliform loading between direct and indirect is based on livestock daily schedules.

In the Mill Creek watershed, it was determined that the only type of livestock that spends any time in confinement is dairy cattle. The initial estimates of the confinement schedules were based on the Middle Blackwater River TMDL. These estimates were presented during the Mill Creek public meetings. The initial numbers were revised based on the stakeholders' comments to reflect the agricultural practices in the watershed.

The directly deposited fecal coliform load from livestock was based on the amount of time livestock spend in the stream. For dairy and beef cattle the amount of time each type spends in the stream are presented in Table 3-14 and Table 3-15. The time beef cattle spend in the stream was also presented during the public meetings where stakeholder provided comments. The monthly time spent in the stream was adjusted to reflect the conditions in the watershed.

Table 3-14: Daily Schedule for Dairy Cattle

Month	Time spent in Pasture (Hours)	Time spent in Stream (Hours)	Time spent in Loafing Lot (Hours)
January	7.45	0.25	16.30
February	7.45	0.25	16.30
March	8.10	0.50	15.40
April	9.35	0.75	13.90
May	10.05	0.75	13.20
June	10.30	1.00	12.70
July	10.80	1.00	12.20
August	10.80	1.00	12.20
September	11.05	0.75	12.20
October	11.00	0.50	12.50
November	10.30	0.50	13.20
December	9.15	0.25	14.60

Source: Mill Creek stakeholders.

Table 3-15: Daily Schedule for Beef Cattle

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	23.50	0.50	0
February	23.50	0.50	0
March	23.25	0.75	0
April	23.00	1.00	0
May	23.00	1.00	0
June	22.75	1.25	0
July	22.75	1.25	0
August	22.75	1.25	0
September	23.00	1.00	0
October	23.25	0.75	0
November	23.25	0.75	0
December	23.50	0.50	0

Source: Mill Creek stakeholders.

The indirect or land based fecal coliform load from livestock was also calculated based on the daily schedule. It accounts for the fecal coliform deposited while livestock are on the pasturelands and land application of the manure generated while dairy cattle are in confinement.

Based on the field survey and interviews, it was determined that horses and sheep spend minimal time in confinement and in the stream. Therefore, the fecal coliform loading from the horses and sheep was considered a land based source. The daily fecal coliform load from horses and sheep was calculated based on the number of horses and sheep in each subwatershed and the daily fecal coliform production per animal. The resulting fecal coliform was applied to the cropland areas in the watershed.

3.5.5 Land Application of Manure

Land application of the manure that dairy cattle produce while in confinement is a typical agricultural practice. In the Mill Creek watershed, the source of the manure for land application is from the five dairy farms in the watershed. This manure is applied to the croplands and some of the pasturelands in the watershed. Typical application rates are 3,000 gallons per acre for liquid manure and 10 tons per acre for solids (Gall, Per. Comm., November 1, 2001).

Manure storage facilities exist at the dairy farms located in the Mill Creek watershed. Two farms have a 180-day storage facility. Two farms have a 120-day storage facility. One farm has a less than 120-day storage facility. For this TMDL development, a minimum of 120 days of storage was used.

3.5.6 Land Application of Biosolids

Nonpoint human sources of fecal coliform can be associated with the spreading of biosolids. There is no biosolid spreading in the Mill Creek watershed; therefore it was not considered in development of the Mill Creek TMDL (Marcussen, Per. Comm., November 1, 2001).

3.5.7 Wildlife

Similar to livestock contributions, wildlife contributions can be both indirect and direct. Indirect sources are those that are carried from land areas of the watershed to the stream through rain and runoff events, where direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and (3) stakeholder comments and observations.

Inventorying wildlife based on habitat availability was a starting point. The number of animals in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities are presented in Table 3-16.

Table 3-16: Wildlife Densities

Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	
Goose	0.004 animals/acre	Within 66 feet of streams and ponds
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding farmsteads and urban land uses

Source: Map Tech, Inc., 2001.

The wildlife inventory presented in Table 3-17 was then confirmed with DGIF and DCR, and was presented to stakeholders and local residents for approval.

Table 3-17: Mill Creek Watershed Wildlife Inventory

Wildlife type	Number of Animals
Deer	1,164
Raccoon	236
Muskrat	991
Beaver	55
Goose	61
Mallard	30
Wood duck	60
Wild Turkey	175

The wildlife inventory was used to determine the fecal coliform loading by wildlife in the watershed. Table 3-18 displays the average fecal coliform production per animal per day contributed by each wildlife type. The distribution of the wildlife daily fecal coliform load between direct and indirect deposits was based on estimates of the amount time each wildlife type spends on the land areas and in the stream. Table 3-18 also shows the percent of time each wildlife type spends in the stream on a daily basis. The portion of the day each wildlife type spends in the stream was used in the distribution of the daily fecal coliform load between direct and indirect deposits.

Table 3-18: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Beaver	0.2	90
Mallard	2,430	50
Wood Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.5.8 Pets

The contribution of fecal coliform loading from pets was examined in estimating the fecal coliform loading to Mill Creek. The primary types of pets considered in this TMDL are cats and dogs. The number of pets residing in the Mill Creek watershed was estimated based on the number of households in the watershed assuming 1.7 dogs and 2.2 cats per household. As previously presented, the total number of households in the watershed was estimated to be 645. Therefore there are a total of 1,419 cats and 1,096 dogs in the watershed.

Fecal coliform loading from pets occurs in residential areas of the watershed. The load was estimated based on the daily fecal coliform production rates of 504 cfu/day per animal for cats and 4.09 x10^9 cfu/day per animal for dogs.

3.6 Existing Best Management Practices

Information about the existing best management practices (BMPs) in the Mill Creek watershed was compiled during interviews with the NRCS, Skyline Soil Water Conservation District, and DCR staff. The BMP information compiled from the interviews was compared to BMP GIS data obtained from DCR. Table 3-19 is a list of the BMP types in the Mill Creek watershed.

The predominant type of BMP in the Mill Creek watershed is alternative water system, followed by grazing land protection. Stream protection (fencing) was found on two unnamed tributaries of Mill Creek.

These BMPs were not widely used in the watershed; therefore the impact of these BMPs on overall fecal coliform loading in the watershed would be negligible.

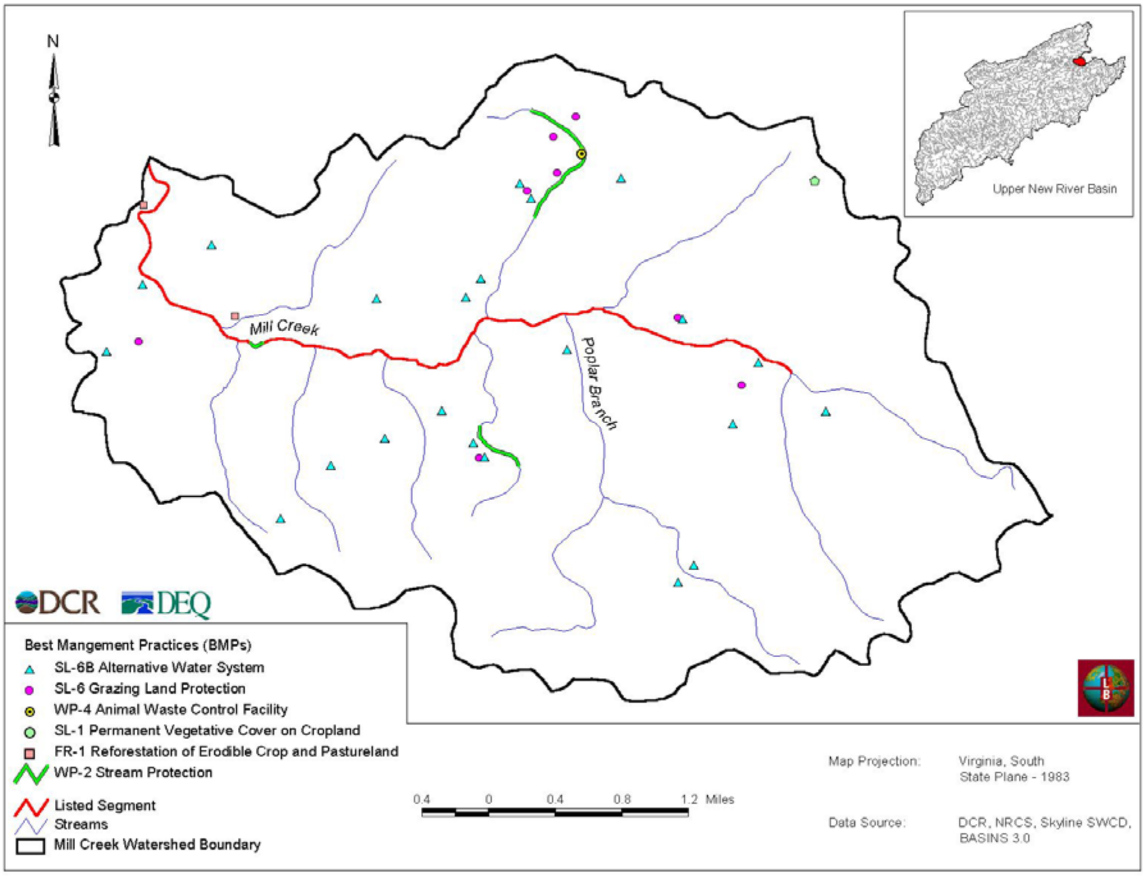
Table 3-19: Inventory of Existing BMPs in the Mill Creek Watershed

BMP	Code	Number
Reforestation of Erodible Crop and Pastureland	FR-1	2
Permanent Vegetative Cover on Cropland	SL-1	1
Grazing Land Protection	SL-6	8
Alternative Water System	SL-6B	22
Stream Protection	WP-2	3
Animal Waste Control Facility	WP-4	1

[1] This can include structural controls such as fencing and livestock watering systems. Rotational grazing can also be included. A livestock watering system can reduce the amount of time spent by each cow by 51 percent.
[2] This helps to keep livestock away from streams without using fencing or other types of structural BMP's.
[3] Small grain cover crops for nutrient management are applied during winter months where no liquid dairy manure is applied to the field therefore its removal efficiency would be zero

Source: DCR, 2000.

Figure 3-10: Best Management Practices (BMPs) in Mill Creek Watershed



4.0 Modeling Approach

This section describes the modeling approach used in the Mill Creek TMDL development. The primary focus is on the sources representation in the model, assumptions used, the model set-up, calibration and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the waterbody that can:

- represent the watershed characteristics;
- represent the point and nonpoint sources of fecal coliform and their respective contribution;
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform);
- estimate the instream pollutant concentrations and loadings under the various hydrologic conditions; and
- allow for direct comparisons between the instream conditions and the water quality standard.

4.2 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the instream water quality conditions of Mill Creek under varying scenarios of rainfall and fecal coliform loading. The results from the developed Mill Creek model were used to develop the TMDL allocations based on the existing fecal coliform load.

HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

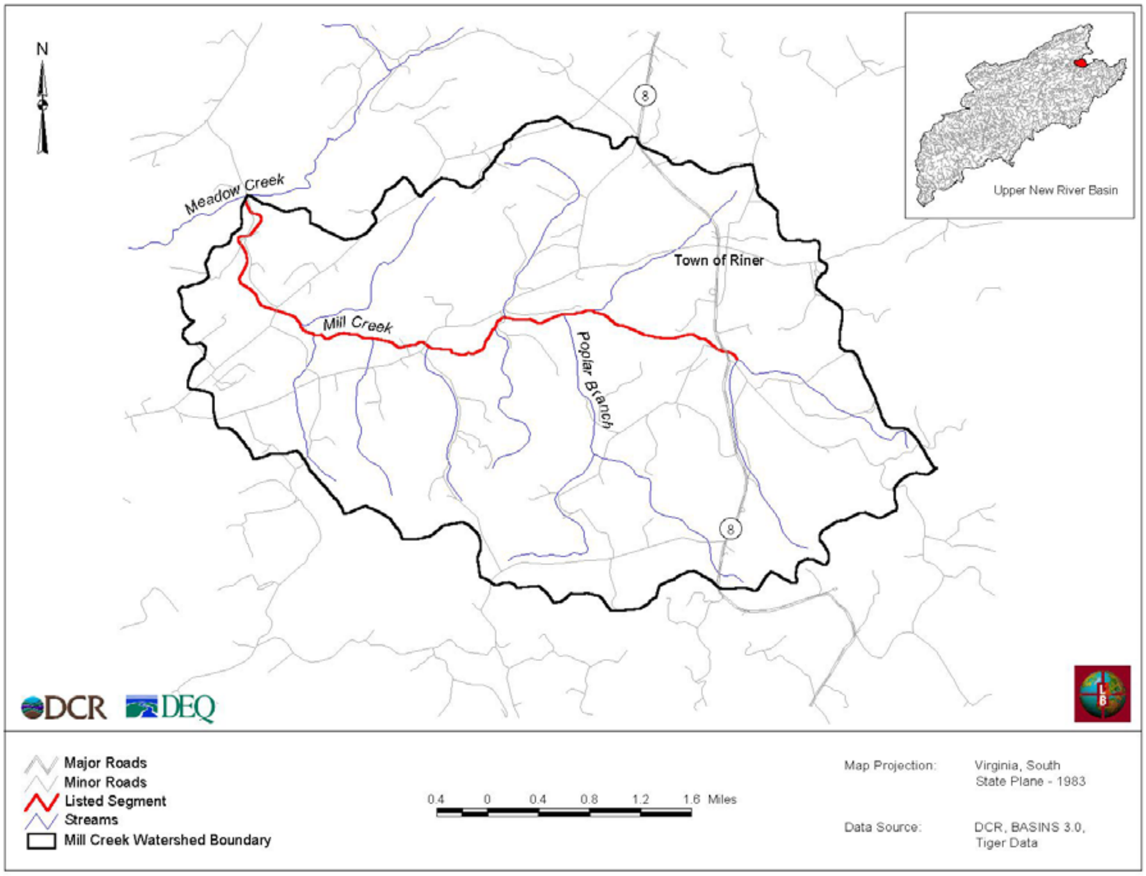
- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment; and
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed.

These steps are discussed in the next few sections.

4.3 Watershed Boundaries

Mill Creek is a tributary of the New River and is a part of the New River Basin. The Mill Creek watershed is approximately 9,308 acres or 14.54 square miles. The watershed is located in southwestern section of Montgomery County, Virginia. State Highway 8 (SH-8) runs through the western section of the watershed in a southerly direction. SH-8 connects the Town of Riner, which is located in the watershed, to Interstate 81 (I-81). Figure 4-1 is a map showing the Mill Creek watershed boundaries.

Figure 4-1: Mill Creek Watershed Boundary



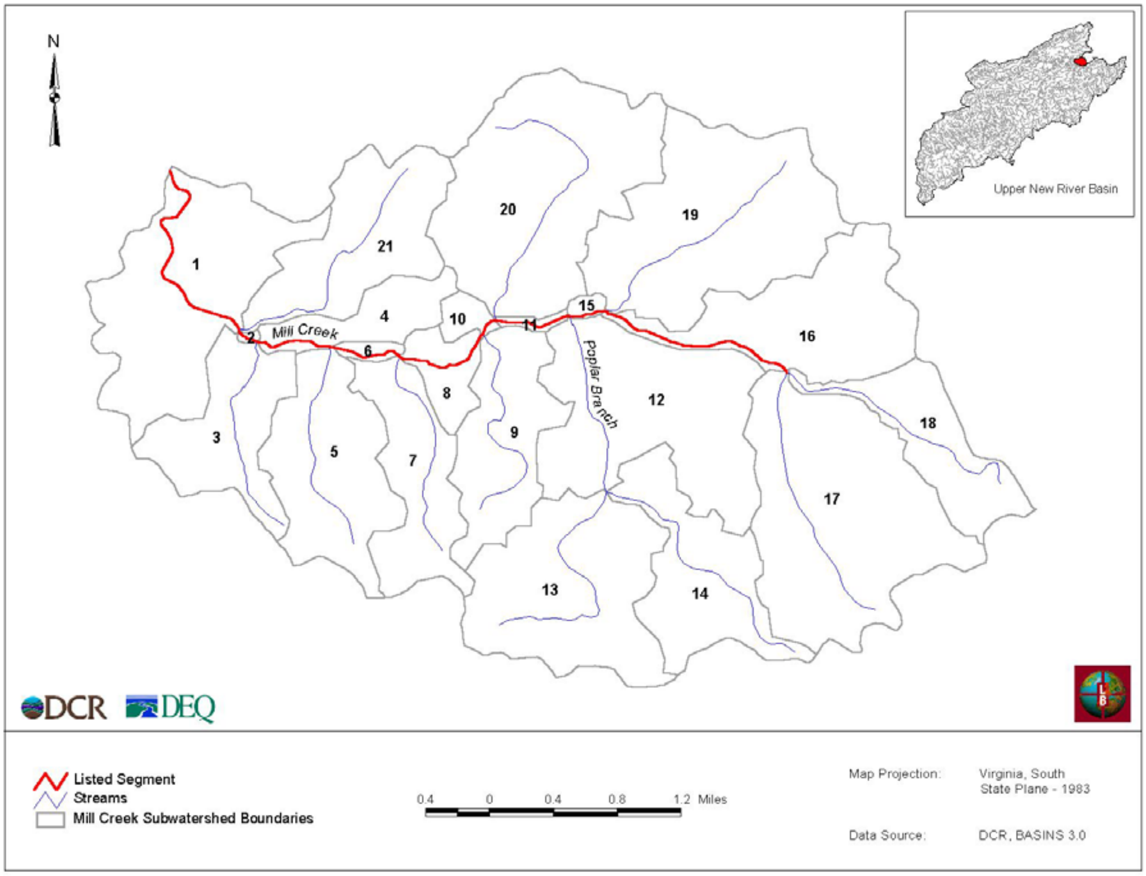
4.4 Watershed Delineation

For this TMDL, Mill Creek watershed was delineated into 21 smaller subwatersheds to represent the watershed characteristics and to improve the HSPF model's accuracy. This delineation was based on the topographic characteristics using the Digital Elevation Model (DEM), the stream reaches using the RF3 data, and the location of stream flow and instream water quality monitoring stations. The sizes of the 21 subwatersheds are presented in Table 4-1. Figure 4-2 is a map showing the delineated subwatersheds for Mill Creek. The Town of Riner is located in subwatersheds 16 and 19.

Table 4-1: Mill Creek Delineated Subwatersheds

Subwatershed	Drainage Area (acres)
1	791.47
2	5.86
3	398.87
4	200.99
5	540.15
6	28.26
7	396.58
8	130.48
9	423.61
10	50.22
11	20.48
12	804.94
13	723.22
14	475.35
15	19.47
16	580.35
17	1012.70
18	347.79
19	899.36
20	951.96
21	506.19
Total	**9,308.30**

Figure 4-2: Mill Creek Subwatershed Delineation



4.5 Land Use Reclassification

As previously mentioned, DCR developed the digital land use data for the Mill Creek watershed and has identified 32 possible land use classes. The land use data and the distribution of land uses in the Mill Creek watershed were presented in Section 3.0. There are 17 land use classes in the Mill Creek watershed; the dominant land uses are improved pasture, forest, and crop land. The original 17 land use types were consolidated into 12 land use categories to meet the modeling goals, to facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 17 land use types to a representative number of land use types that best describe the Mill Creek watershed conditions and the dominant fecal coliform source categories. The land use reclassification was based on similarities in hydrologic and potential fecal coliform production characteristics. The reclassified land uses are presented in Table 4-2.

Table 4-2: Mill Creek Land Use Reclassification

Reclassified Land Use	DCR Land Use Type	Acres	Percent
High Density Residential	Mobile Home Park	8.98	0.10
Medium Density Residential	Medium Density Residential, Barren	109.17	1.17
Low Density Residential	Low Density Residential, Barren	213.29	2.29
Commercial/Industry	Commercial and Services, Industry, Transportation,	100.88	1.08
Other Urban	Open Urban Land, Mixed Urban or Built-up Land	49.94	0.54
Improved Pasture	Improved Pasture/Permanent Hay	5630.97	60.50
Unimproved Pasture	Unimproved Pasture, Grazed Woodland	76.85	0.83
Crop	Crop Land	960.00	10.31
Farmstead	Farmstead	112.73	1.21
Forest	Forested	2035.55	21.87
Wetlands	Wetlands	3.35	0.04
Water	Water	6.18	0.07
Total		9307.86	100.00

4.6 Hydrographic Data

Hydrographic data that describe the stream network and reaches were obtained from the Reach File Version 3 (RF3) contained in BASINS. There data were used for the HSPF model and TMDL development. The reach number, reach name, and length are included in the RF3 database. Names of some reaches were added to the RF3 database using information from the USGS 7.5 minute quadrangle maps for Riner and Radford South, Virginia. Table 4-3 provides a summary of the reach information for the Mill Creek watershed.

Table 4-3: Mill Creek RF3 Reach Information Summary

Reach Number	Reach Name	Length (miles)
5050001 96 0.00	Mill Creek	1.50
5050001 96 1.36	Mill Creek	0.15
5050001 96 1.50	Mill Creek	0.49
5050001 96 1.95	Mill Creek	0.48
5050001 96 2.39	Mill Creek	0.65
5050001 96 2.98	Mill Creek	0.14
5050001 96 3.11	Mill Creek	0.48
5050001 96 3.55	Mill Creek	0.24
5050001 96 3.77	Mill Creek	1.26
5050001 96 4.92	Mill Creek	1.72
5050001 524 0.00	Unnamed Tributary	1.35
5050001 525 0.00	Unnamed Tributary	1.39
5050001 526 0.00	Unnamed Tributary	1.40
5050001 527 0.00	Unnamed Tributary	1.55
5050001 528 0.00	Poplar Branch	1.18
5050001 528 1.18	Unnamed Tributary	1.75
5050001 529 0.00	Unnamed Tributary	1.66
5050001 530 0.00	Unnamed Tributary	1.72
5050001 531 0.00	Unnamed Tributary	1.56
5050001 532 0.00	Unnamed Tributary	1.92
5050001 533 0.00	Unnamed Tributary	1.67

The stream geometry was field surveyed for representative reaches of Mill Creek. The stage flow relationship that is required by HSPF was developed based on the USGS stream flow gage data for Tinker Creek. The relationship was then transferred to the Mill Creek watershed based on the drainage area weighted method to determine the function tables (F-Tables) for the 21 stream segments.

Mill Creek and its tributaries were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation using a 0.05 roughness coefficient.

Model representation of the Mill Creek stream reach segments is presented in Appendix A.

4.7 Fecal Coliform Sources Representation

This section will show how the fecal coliform sources identified in Section 3.0 were included or represented in the model. These sources include permitted sources, human sources (failed septic systems and straight pipes), livestock, wildlife, pets, and land application of manure and biosolids.

4.7.1 Permitted Facilities

The only permitted discharger in Mill Creek watershed is the Riner Sewage Treatment Plant (STP). Table 4-4 shows the permitted facility identification number, the stream reach receiving the discharge, facility design discharge rate, and the permitted fecal coliform concentration.

The Montgomery County Public Sewer Authority provided maps that show the extent of the sewer system in the area (Mabry, 2001). The sewage collected from the 79 households connected to the network is conveyed to the STP located in the southern section of the Town of Riner. Based on data from DEQ's West Central Regional Office, a discharge rate of 10,000 gallons per day (gpd) is considered representative of the existing condition of the Riner STP. This discharge rate was used in the HSPF model calibration and validation.

For the TMDL allocation development the Riner STP was represented as a constant source discharging 100,000 gpd and a fecal coliform concentration of 200 cfu/100 ml.

Table 4-4: Permitted Dischargers in the Mill Creek Watershed

Permit Number	Receiving Stream Reach	Design Flow (gpd)[1]	Fecal Coliform Concentration (cfu/100ml)	Status
VA0024040	Mill Creek (5050001 96 3.77)	100,000	200	Active

1. gpd: gallons per day

4.7.2 Failed Septic Systems

Failed septic system loading to Mill Creek can be direct (point) or land-based (indirect or nonpoint) depending on the proximity of the septic system to the stream. In cases where the septic system is within the 20-foot stream buffer, the failed septic system was represented as a constant source (similar to a permitted facility) in the model.

As explained in Section 3.0, the total number of septic systems in the watershed was estimated at 566 systems and it was determined that 491 of these septic systems have been operating since 1978. Based on GIS data, only 15 of the 566 households on septic systems where located in the 20-foot stream buffer. Not all septic systems located within the stream buffer are considered failed systems, so only a fraction of 15 systems were included in the model as constant sources.

For this TMDL development, it was assumed that a 1.5% failure rate for septic systems would be representative of the watershed conditions. This corresponds to a total of 9 failed septic systems in the watershed. To account for uncontrolled discharges in the watershed and failed septic systems within the stream buffer, a total of 5 straight pipes were included in the model. This estimate was based on field observations, discussions with DCR, DEQ, stakeholder comments and evaluation of the BST results.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100ml were used in the fecal coliform load calculations. The fecal coliform loading from failed septic systems that are not with in the 20 buffer of the stream is considered to be a predominantly indirect source. Failed septic systems within the stream buffer and straight pipes were represented as a constant source of fecal coliform. Table 4-5 shows the distribution of the septic systems and the straight pipes in the Mill Creek watershed.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100ml were used in the fecal coliform load calculations.

The load from septic systems is presented in Appendix B.

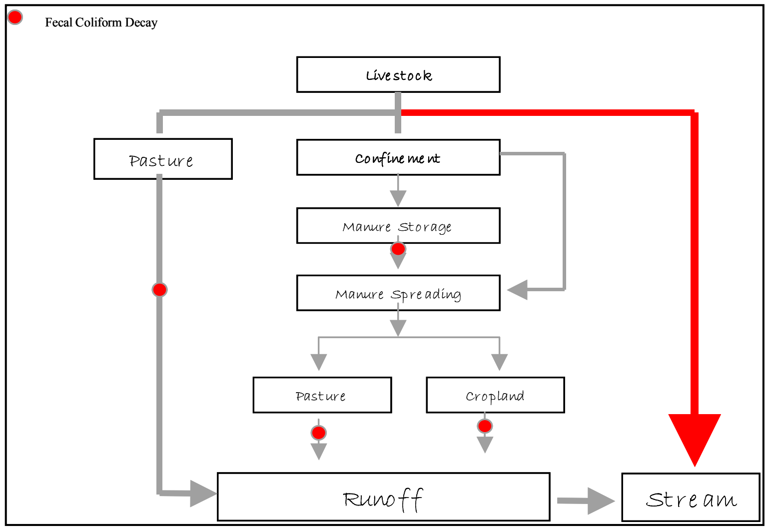
Table 4-5: Failed Septic Systems and Straight Pipes Assumed in Model Development

Subwatershed ID	Number of septic systems	Number of Failed Septic Systems	Number of straight pipes
1	65	1	1
2	1	0	0
3	62	1	1
4	2	0	0
5	5	0	0
6	0	0	0
7	12	0	0
8	0	0	0
9	3	0	0
10	0	0	0
11	0	0	0
12	9	0	0
13	20	0	0
14	37	1	0
15	0	0	0
16	76	1	1
17	38	1	0
18	7	0	0
19	166	3	2
20	45	1	0
21	18	0	0
Total	566	9	5

4.7.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in Figure 4-3. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, the land-based fecal coliform deposited by livestock while grazing.

Figure 4-3: Livestock Contribution to Mill Creek Watershed



Based on the inventory of livestock in the Mill Creek watershed, it was determined that dairy and beef cattle are the predominant types of livestock, though horses and sheep are also present. The inventory also indicated that there are no poultry operations, goats, or swine in the watershed.

The distribution of the daily fecal coliform load between direct instream and indirect (land-based) loading was based on the livestock daily schedules. In the Mill Creek watershed, it was determined that the only type of livestock that spends any time in confinement is dairy cattle. The other livestock do not spend any time in confinement.

The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spend in the stream. The amount of time livestock spend in the stream was presented in Section 3.0.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in Appendix B.

The fecal coliform deposited while in confinement is collected and later spread onto crop and pasture lands in the watershed. This type of loading is addressed in the next section.

4.7.4 Land Application of Manure

In the Mill Creek watershed, five dairy farms practice the spreading of manure on crop and pasture lands. Manure deposited while cattle are in confinement is collected for application on crop and pasture lands. The loading from land application of manure was estimated based on the total number of dairy cattle in the watershed, the fecal coliform production per animal per day, and percent of the time the cattle spend in confinement. For this TMDL, the distribution of the produced manure was 75% cropland and 25% pastureland and the typical application rates are 3,000 gallons per acre for liquid manure and 10 tons per acre for solids (Gall, 2001).

As previously mentioned the dairy farms in the watershed do not land apply fresh manure to the crop and pasture lands. The existing manure storage facilities on these farms range from 120 to 180 days. For this TMDL development, 120 days of manure storage before application was considered representative. To account for this storage and the resulting reduction in the fecal coliform counts, the fresh manures load estimates were reduced substantially based on the die-off rate of 0.05 per day corresponding to 120 days. This resulted in a 99.7 percent reduction in the fresh manure fecal coliform content.

Because land-applied manure to cropland is incorporated into the soil by plowing, not all of the manure that is land applied is available for runoff. Therefore it was assumed that only 70 percent of this applied livestock manure would be available for runoff.

4.7.5 Land Application of Biosolids

There is no land application of biosolids in the Mill Creek watershed, therefore it was not considered in development of the Mill Creek TMDL (Marcussen, Per. Comm., 2001).

4.7.6 Wildlife

The fecal loading from wildlife was estimated the same way loading from livestock was calculated. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on the amount of time each wildlife type spend on the land and in the stream.

In the wildlife inventory (Section 3.0), the daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented. The direct fecal coliform load from wildlife was calculated by multiplying the number of each wildlife type in the watershed by the fecal coliform production per animal per day, and the percent of time each animal spends in the stream. The indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each wildlife type in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on the land areas in the Mill Creek watershed. The resulting fecal coliform loading was then distributed on forest, pasture, cropland uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre) then by multiplying by the total area of pasture, cropland, and forest in each subwatershed.

The fecal coliform loading from wildlife is presented in Appendix B.

4.7.7 Pets

For the Mill Creek TMDL, the pet fecal coliform loading was considered a land-based load that is primarily deposited on the residential areas in the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per pet type.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the Mill Creek watershed. Three fecal coliform die-off rates required by the model to accurately represent the conditions in the watershed are:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in-storage facilities.
2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.
3. **Instream fecal coliform die-off**. Fecal coliform directly deposited into the stream as well as fecal coliform that enters the stream from indirect sources will undergo decay.

In the Mill Creek TMDL, in-storage die-off was implicitly included in the model. The fresh manure fecal coliform content was reduced to reflect the die-off that would take place during 120 days of storage. An in-storage fecal coliform die-off rate of 0.05 per day was used. An on-surface fecal coliform die-off rate of 1.37 per day was used. Finally, the instream fecal coliform die-off rate of 1.152 per day was used (EPA, 1985).

4.9 Model Set-up, Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) to make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to the observed data set, which is different from the one used in the calibration process, and estimating the model's prediction accuracy. The hydrologic processes of the model were calibrated, then the water quality processes were calibrated.

4.9.1 Model Set-Up

The HSPF model was set up and calibrated based on the Tinker Creek flow data and watershed characteristics, because there were no available stream flow data for Mill Creek. Tinker Creek is located in Botetourt and Roanoke Counties and is a tributary to the Roanoke River. Mill Creek and Tinker Creek are hydrologically similar. The hydrologic similarity between the two watersheds was established by analyzing the land use conditions, drainage areas, slopes, and soil types.

4.9.1.1 Paired Watershed Approach

Since no stream flow monitoring data exist in the Mill Creek watershed, the paired watershed approach was used to set-up and calibrate the HSPF model. The basis of this approach is to develop the model for a hydrologically similar watershed where data are available, then to transfer the calibrated model to the watershed with the insufficient data. The criteria used to evaluate the similarity in hydrologic characteristics of the watershed include watershed physiographic characteristics (drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, land use land cover) and mean annual precipitation.

Five stream flow gages were identified for potential use in the paired watershed approach that included Wilson Creek, Tinker Creek, Crab Creek, Chestnut Creek, and Smith River. As explained in Section 3.0, it was determined that Tinker Creek would be used in this paired watershed approach.

The first step in the paired watershed approach is to examine the hydrologic similarity between the Tinker Creek and Mill Creek watersheds. The land uses were divided into three categories: urban, non-urban, and other land uses. Table 4-6 shows these categories and the land use distribution in each category for the two watersheds. The non-urban land uses category that includes forest, pasture and crop land areas account for 98% of the Tinker Creek watershed and 94% of the Mill Creek watershed. This indicates that land use in the Tinker Creek watershed is representative of the land use in the Mill Creek watershed.

Table 4-6: Summary of Land Use Distributions for Tinker Creek and Mill Creek

Category	Land Use	Tinker Creek		Mill Creek	
		Acre	%	Acre	%
Non-urban land uses	Forest	3172.70	42.07	2035.55	21.87
	Pasture/Hay	4150.82	55.04	5754.05	61.82
	Row Crops	73.19	0.97	960.00	10.31
	Total Non-urban Land Uses	**7396.71**	**98.07**	**8749.60**	**94.00**
Urban land uses	Low Intensity Residential	89.28	1.18	326.02	3.50
	Medium Density Residential	0.00	0.00	109.17	1.17
	High Intensity Residential	0.00	0.00	8.98	0.10
	Open Urban	0.00	0.00	0.00	0.00
	Other Urban	21.39	0.28	3.71	0.04
	Commercial/Industrial/Transportation	3.44	0.05	100.88	1.08
	Total Urban Land Uses	**114.11**	**1.51**	**548.76**	**5.90**
Other land uses	Wetlands	2.36	0.03	3.35	0.04
	Water	28.87	0.38	6.18	0.07
	Total	**7,542.05**	**100**	**9,307.89**	**100**

In addition to the land use, the soil distribution in the watersheds was analyzed. Table 4-7 shows the soil types and distribution in each watershed. The soils series present in both the Tinker Creek and Mill Creek watersheds consists of well-drained soils. Based on the hydrologic soil group classification, the soil series present in the two watersheds range from B to C.

Table 4-7: Soil Distribution in Tinker Creek and Mill Creek

Soil Id	Soil Name	Hydrologic Group	Percent of Watershed	
			Tinker Creek	Mill Creek
VA002	Carbo-Chilhowie-Frederick	B/C	50%	
VA003	Fredrick-Carbo-Timberville	B/C	40%	
VA005	Wallen-Dekalb-Drypond	B/C	10%	
VA 017	Berks-Groseclose-Lowell	B/C		85%
VA 001	Berks-Lowell-Rayne	B/C		15%

Additional watershed characteristics of Tinker Creek and Mill Creek, including the drainage area, main channel slope, main channel length, and the mean basin elevation, were compared. The data, presented in Table 4-8, indicates that these physical characteristics of the watershed are similar.

Table 4-8: Comparison of Tinker Creek and Mill Creek Watershed Characteristics

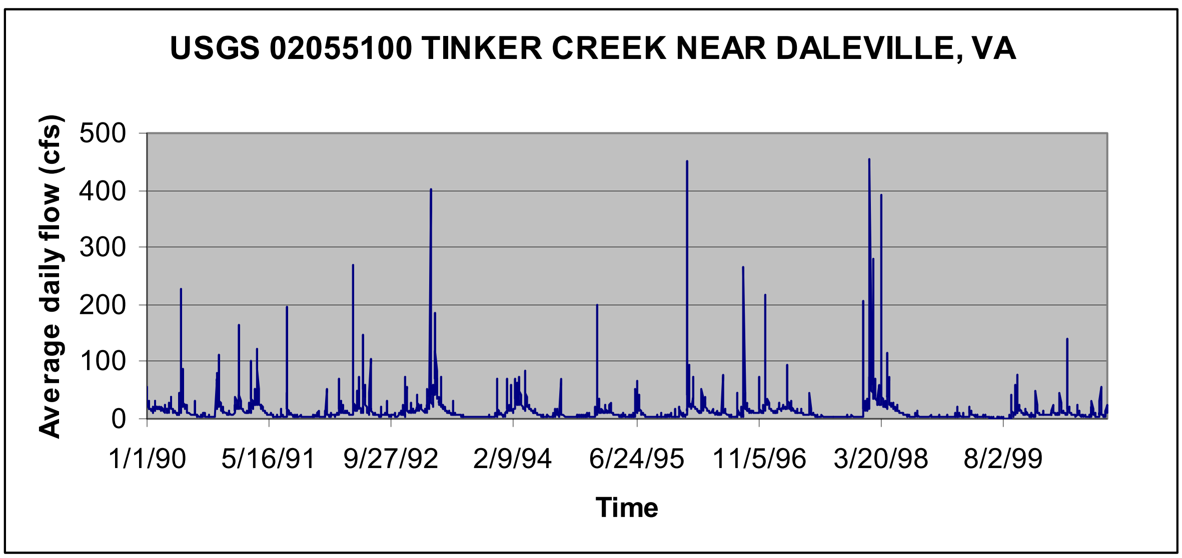
Watershed	Drainage Area (square miles)	Main Channel Slope (feet/mile)	Main Channel Length (mile)	Mean Basin Elevation (feet)
Tinker Creek	11.7	50	4.43 mi	1400
Mill Creek	12.5	57	7.0 mi	2000

Based on the land use data, soil distribution, the watershed physical characteristics, the Tinker Creek watershed is hydrologically similar to Mill Creek watersheds. Therefore, the Tinker Creek watershed for which there are sufficient data, can be used as a surrogate for setting up and calibrating the HSPF model. The model will then be transferred to Mill Creek and used in the TMDL development.

4.9.1.2 Stream Flow Data

The Tinker Creek watershed was chosen as a surrogate location for calibration of the Mill Creek hydrologic model because there are no available stream flow data for Mill Creek and the Tinker Creek watershed in hydrologically similar to the Mill Creek watershed. There is a continuous flow gage (USGS 02055100) located near Daleville on Tinker Creek. This gage recorded daily flow data from May 1, 1956 to September 30, 2000. The data was retrieved from the USGS Web site (www.usgs.gov). The average daily flow data for the period from 1990 to 2000 was retrieved and plotted in Figure 4-4. The average flow of Tinker Creek ranged from 0.59 to 454cfs with an average flow of 12.9cfs.

Figure 4-4: Daily Mean Flow (cfs) at USGS Gaging Station 02055100



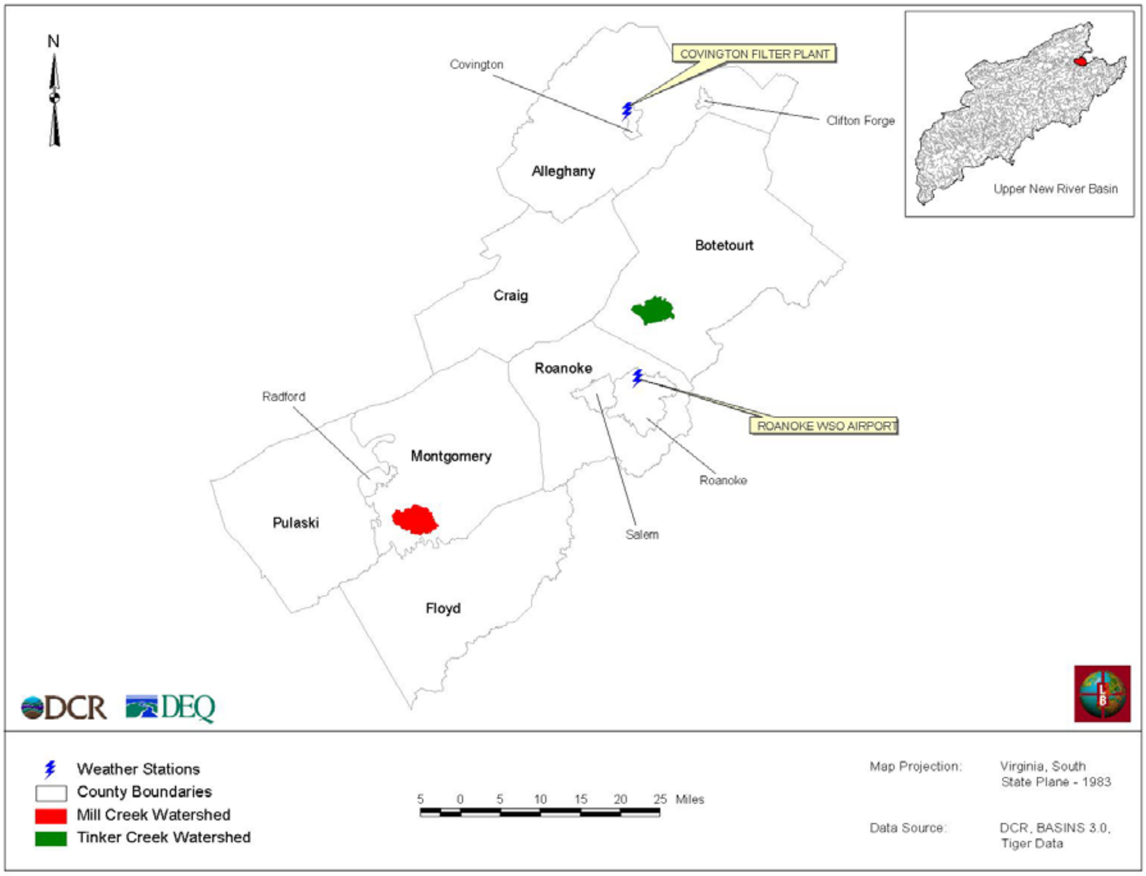
A five-year period (1993-1998) was selected as the calibration period for the Tinker Creek model.

4.9.1.3 Rainfall and Climate Data

Hourly precipitation, temperature, solar radiation, wind, and relative humidity data were obtained from the weather station at the Roanoke Regional Airport which is located approximately 8.5 miles south of the watershed. After some initial model runs, it was evident that the Roanoke Regional Airport data could not adequately explain the observed stream flow at the USGS gage (02055100) on Tinker Creek near Daleville. There were significant discrepancies during some large storm events. Therefore, hourly precipitation data from the Covington Filter Plant, which is located 25.5 miles north of the Tinker Creek watershed, was used in addition to the Roanoke data to develop a synthetic precipitation time series representative of the Tinker Creek watershed. Figure 4-5 is a map showing the rainfall gages location. Precipitation values recorded at the Roanoke Airport and the Covington Filter Plant were multiplied by 0.75 and 0.25, respectively, and added to compute the synthetic precipitation time-series. These multiplication factors are proportional to the inverse of the distances of weather stations from the watershed. The synthetic precipitation data and other weather data collected at the Roanoke Regional Airport were used as input to the Tinker Creek model.

For the TMDL development the rainfall and climate data from Roanoke Regional Airport were used in the set-up of the Mill Creek HSPF model.

Figure 4-5: Rainfall Gages Location



4.9.2 Model Hydrologic Calibration Results

The HSPEXP, an expert system software (Lumb and Kittle, 1993) was used to calibrate HSPF for the Tinker Creek watershed. After each iteration of the model run, HSPEXP calculates certain statistics and compares the model results with observed values to provide guidance on parameter adjustment according to the built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

For the period from September 1993 to August 1998 and using the recommended default criteria in HSPEXP as target values for an acceptable hydrologic calibration, the Tinker Creek model was calibrated; results are presented in Table 4-9. The table shows the simulated and the observed values for nine flow characteristics. The error statistics summary for seven flow conditions for the calibration is presented in Table 4-10. The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-11. The model results and the observed daily average flow at Tinker Creek are plotted in Figure 4-6.

Table 4-9 Tinker Creek Model Calibration Results

Category	Simulated	Observed
Total annual runoff, in inches	128.10	124.45
Total of highest 10% flows, in inches	52.95	51.59
Total of lowest 50% flows, in inches	20.11	19.90
Total storm volume, in inches	17.28	12.46
Average of storm peaks, in cfs	100.1	102.70
Baseflow recession rate	0.96	0.95
Summer flow volume, in inches	21.68	18.98
Winter flow volume, in inches	48.79	43.04
Summer storm volume, in inches	0.9	0.69

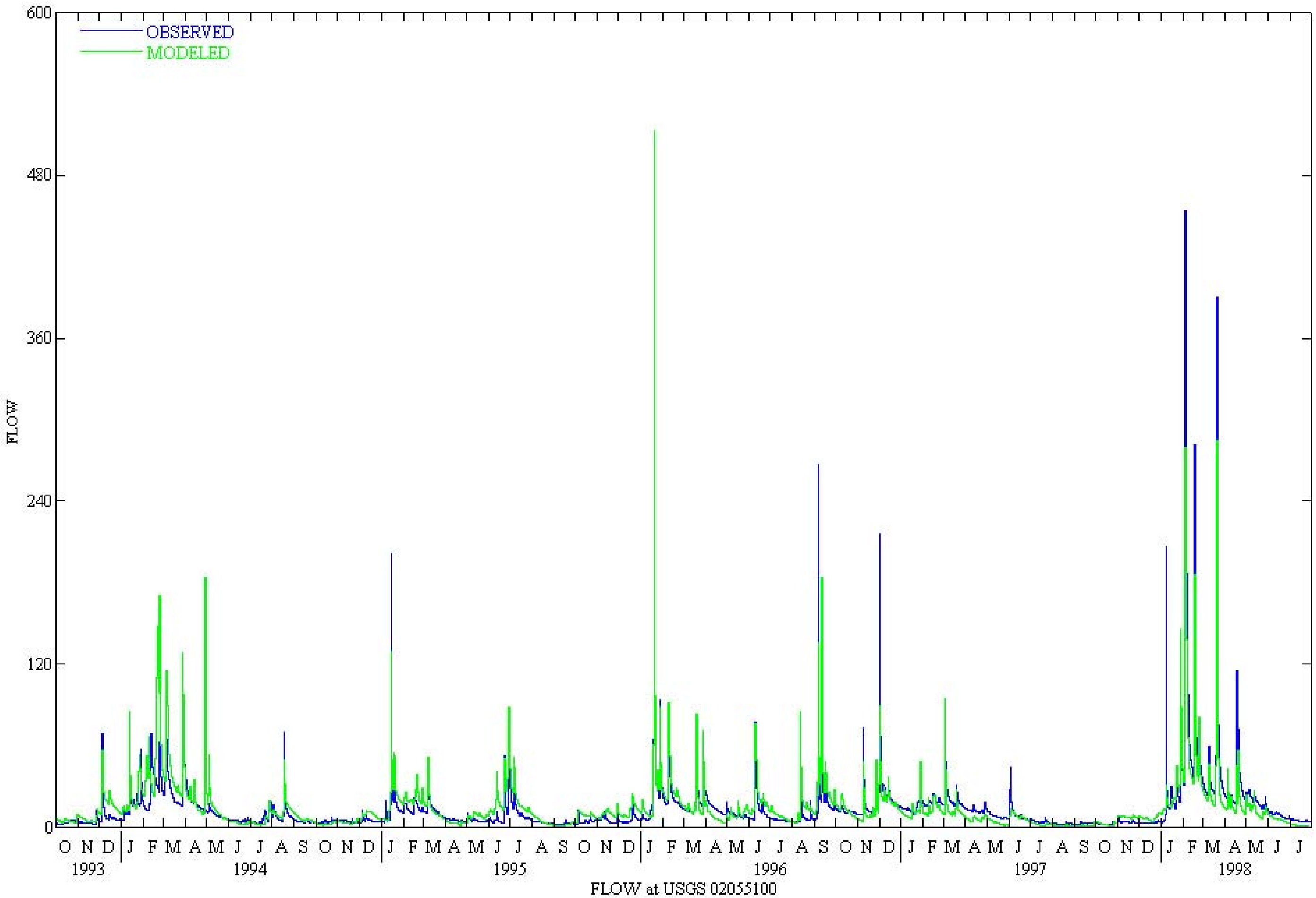
Table 4-10: Tinker Creek Model Calibration Error Statistics

Category	Current	Criterion
Error in total volume	2.900	± 10.000
Error in low flow recession	-0.010	± 0.010
Error in 50% lowest flows	1.100	± 10.000
Error in 10% highest flows	2.600	± 15.000
Error in storm volumes	-2.500	± 15.000
Seasonal volume error	0.800	± 10.000
Summer storm volume error	-8.100	± 15.000

Table 4-11: Tinker Creek Simulation Water Budget

Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
1993	3.44	5.21	14.20	15.05%	22.80%	62.14%
1994	1.32	6.02	16.70	5.49%	25.04%	69.47%
1995	0.63	2.26	14.60	3.62%	12.92%	83.46%
1996	2.86	6.14	18.20	10.51%	22.57%	66.91%
1997	0.18	0.97	8.00	1.97%	10.55%	87.48%
Average				**7.33%**,	**18.78%**,	**73.89%**.

Figure 4-6: Tinker Creek HSPF Model Hydrologic Calibration Results



4.9.3 Model Hydrologic Validation Results

The period from October 1999 to September 2000 was used to validate the HSPF model. The validation results are presented in Figure 4-7 and the summary statistics from HSPEXP are presented in Table 4-12 and Table 4-13. The error statistics indicate that the validation results were within the recommended ranges in HSPEXP.

The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-15.

Table 4-12: Tinker Creek Model Validation Results

Category	Simulated	Observed
Total annual runoff, in inches	146.900	142.300
Total of lowest 50% flows, in inches	23.300	23.070
Total of highest 10% flows, in inches	60.140	59.480
Total storm volume, in inches	4.150	4.149
Average of storm peaks, in cfs	25.750	29.180
Base flow recession rate	0.960	0.960
Summer flow volume, in inches	24.950	21.650
Winter flow volume, in inches	53.870	47.020
Summer storm volume, in inches	0.300	0.267

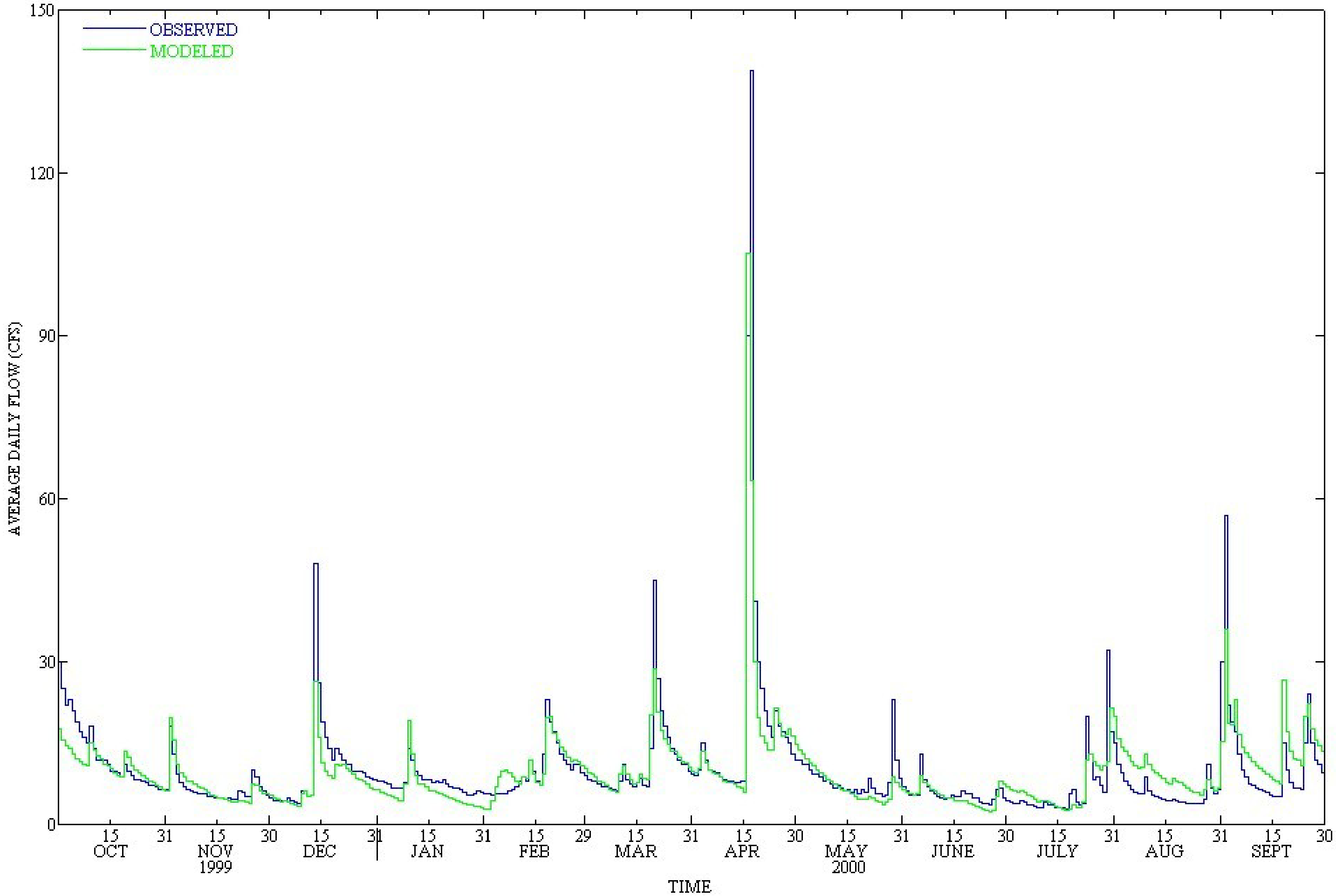
Table 4-13: Tinker Creek Model Validation Error Statistics

Category	Current	Criteria
Error in total volume	3.200	10.000
Error in low flow recession	0.000	0.010
Error in 50% lowest flows	1.000	10.000
Error in 10% highest flows	1.100	15.000
Error in storm volumes	11.800	15.000
Seasonal volume error	0.600	10.000
Summer storm volume error	12.40	15.000

Table 4-14: Tinker Creek Validation Water Budget

Water Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
1999	0.05	0.29	8.05	0.6%	3.5%	95.9%
2000	0.43	1.27	11.58	3.2%	9.6%	87.2%
Average	0.24	0.78	9.81	1.9%	6.6%	91.5%

Figure 4-7: Tinker Creek - HSPF Model Hydrologic Validation Results



There is a good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. The model results closely match the observed flows during low flow conditions, base flow recession and storm peaks. The final parameter values of the calibrated model are listed in Table 4-15.

Table 4-15: Tinker Creek Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Tinker Creek
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0.00	0.5	0	0.95	0.0, 1.0
LZSN	Lower zone nominal soils moisture	inch	3	8	2	15	0.9-1.0
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.001	0.5	0.14-0.17
LSUR	Length of overland flow	Ft	200	500	100	700	200
SLSUR	Slope of overland flowplane	None	0.01	0.15	0.001	0.3	0.02
KVARY	Groundwater recession variable	1/inch	0	3	0	5	0.0
AGWRC	Basic groundwater recession	None	0.92	0.99	0.85	0.999	0.95
PETMAX	Air temp below which ET is reduced	Deg F	35	45	32	48	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	30	40	35
INFEXP	Exponent in infiltration equation	None	2	2	1	3	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	3	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	0.00
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	0.03

Parameter	Definition	Units	Typical		Possible		Tinker Creek
			Min	Max	Min	Max	
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	0.0
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.01	0.4	Monthly[1]
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.05	2	1.3-1.6
NSUR	Manning's n	None	0.15	0.35	0.1	0.5	0.25
INTFW	Interflow/surface runoff partition parameter	None	1	3	1	10	1.0
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	0.3
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	Monthly[1]
RETSC	Retention storage capacity of the surface	inch					
ACQOP	Rate of accumulation of constituent	#/ac day					7.6E7-2E10
SQOLIM	Maximum accumulation of constituent	#					1E8 to 3E10
WSQOP	Wash-off rate	Inch/hour					0.70 – 1.5
IOQC	Constituent concentration in interflow	#/CF					5
AOQC	Constituent concentration in active groundwater	Cfu/100 ml					1
KS	Weighing factor for hydraulic routing						0.5
FSTDEC	First order decay rate of the constituent	1/day					1.15
THFST	Temperature correction coefficient for FSTDEC	none					1.07

4.9.4 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off and kinetic rates for fecal coliform that best describe the fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available instream fecal coliform data and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated instream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The available instream water quality data plays a major factor in determining the calibration and validation periods for the model. In Section 3.0, the instream monitoring stations were listed and the sampling events conducted on Mill Creek were summarized and presented. Station 9-MLC000.17 is the most downstream station but unfortunately has limited data. Only, five sampling events were conducted for the 1999 to 2000, which was dominated by low rainfall and stream flow conditions, therefore, it was determined that this station would not be appropriate for the water quality calibration. Station MLC001.31 is upstream of station 9-MLC000.17 and similarly, it was not selected for the model calibration because only five sampling events were conducted for the 1999 to 2000 period.

Station 9-MLC005.44 has water quality data from 1988 to 2001 representing a total of 75 sampling events. The water quality data for this station was retrieved from STORET and DEQ and evaluated for potential use in the set-up, calibration, and validation of the water quality model. The period from January 1994 to December 1995 was used for the water quality calibration of the model and the period from January 1996 to December 1998 was used for the model validation.

It important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model-simulated fecal coliform concentrations represent the average daily values. The model-simulated results and the observed fecal coliform values were plotted and are presented in Figure 4-8 and Figure 4-9. The goodness of fit for the water quality calibration was visually evaluated. Analysis of model results indicates that the model is well-calibrated since it can predict the range of fecal coliform concentration under the wet and dry weather conditions.

Figure 4-8: Water Quality Calibration

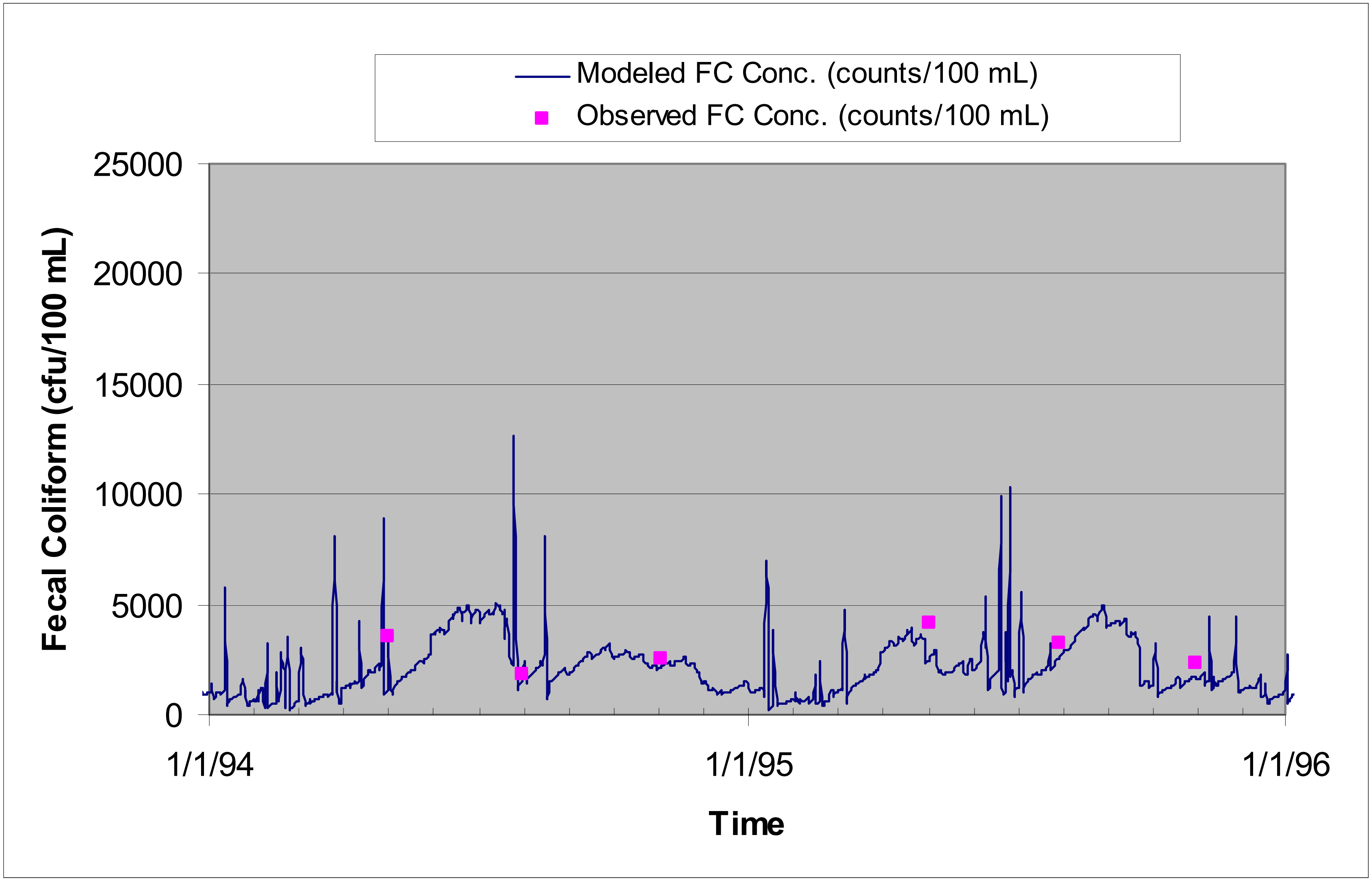
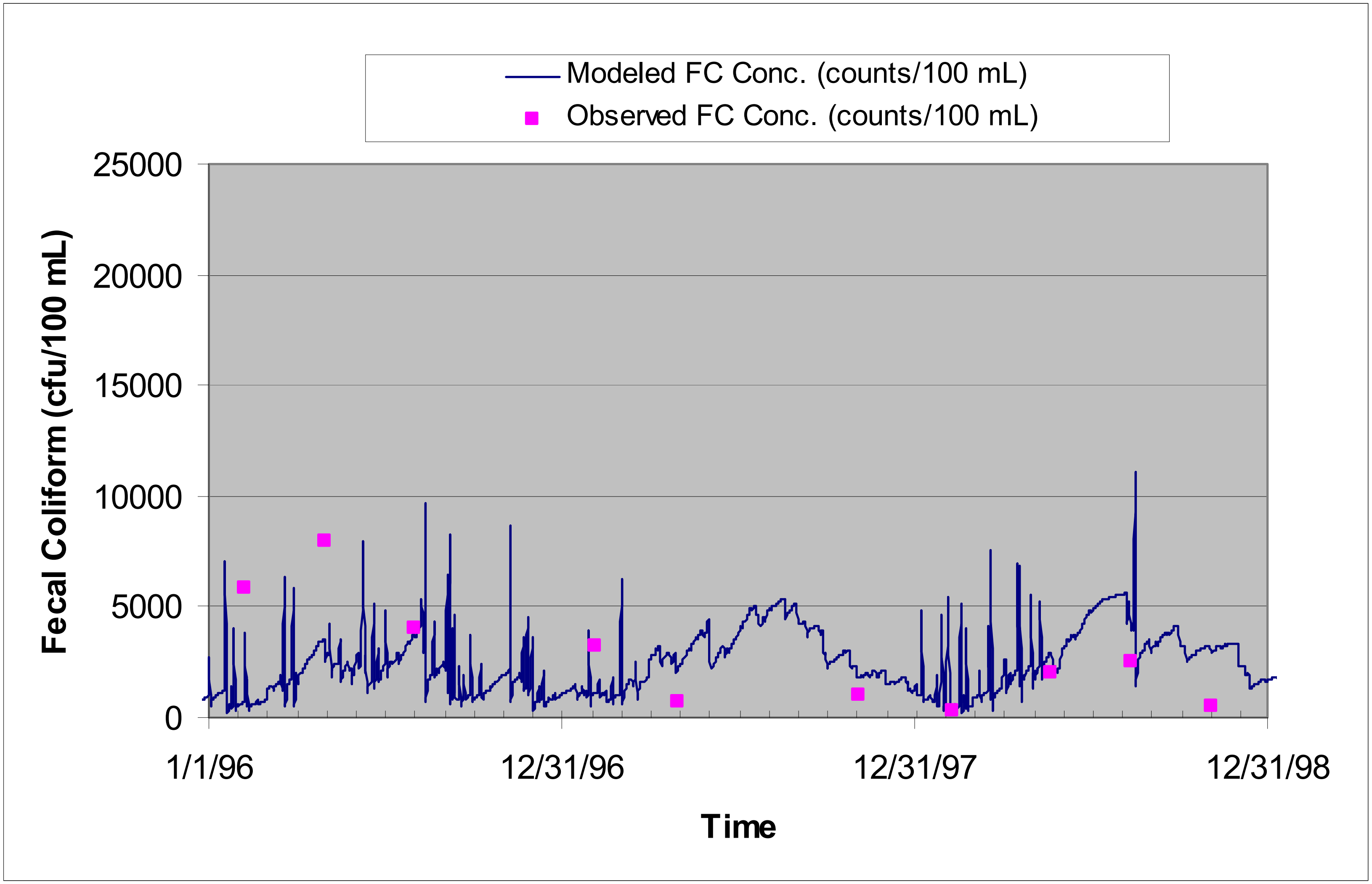


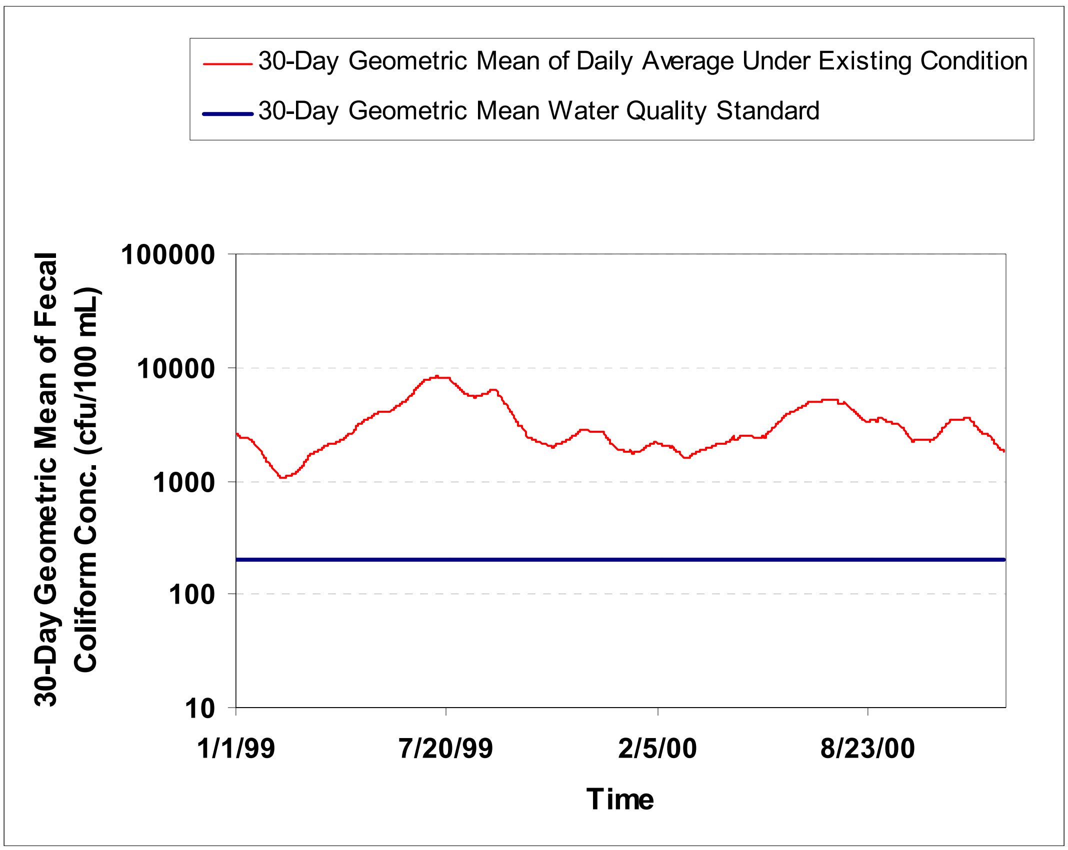
Figure 4-9: Water Quality Validation



4.10 Existing Fecal Coliform Loading

The existing fecal coliform loading was calculated based on the existing watershed conditions. The model input parameters reflect the conditions for the period from 1999 to 2000. Figure 4-10 shows the 30-day geometric mean fecal coliform concentration in Mill Creek. The figure shows that the 200 cfu/100 ml standard was exceeded all the time.

Figure 4-10: Existing Conditions in Mill Creek



The distribution of the existing fecal coliform load by source is presented in Table 4-16 and it shows that fecal coliform loading from pasture, cattle direct deposition, and wildlife direct deposition are the predominant sources of fecal coliform in the watershed.

Table 4-16: Fecal Coliform Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent
Forest	4.89E+11	0.05
Low Intensity Residential	1.35E+12	0.13
Pasture/Hay	5.03E+14	50.5
Row Crops	6.58E+11	0.07
Med Intensity Residential	7.47E+11	0.07
Unimproved Pasture/Hay	2.50E+09	0.0002
Commercial/Industry/Transportation	5.19E+10	0.01
Farmstead	7.27E+11	0.07
Septic load	1.13E+11	0.01
Direct deposition from cattle	4.25E+14	42.5
Direct deposition from wildlife	6.66E+13	6.7
Point Source (1)	2.62E+11	0.03
Total	**9.99E+14**	**100.00**

5.0 Allocation

For the Mill Creek fecal coliform TMDL, allocation analysis was the third stage in development. Its purpose is to develop the framework for reducing fecal coliform loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source allocation); and

MOS = margin of safety, 5% of TMDL.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be explicitly incorporated into this TMDL. Incorporating a MOS of 5% will require that allocation scenarios be designed to meet the 30-day fecal coliform geometric mean standard of 190 cfu/100 ml with 0% exceedance.

5.2 Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Based on the sensitivity analysis and consultation from DCR, several allocation scenarios were developed; these are presented in the next section. For each scenario developed the percent of days the water quality conditions violate both the 30-day geometric mean standard and the instantaneous fecal coliform standard is shown.

The results of the sensitivity analysis are presented in Appendix D.

5.3 Allocation Scenario Development

Allocation scenarios that would reduce the existing fecal coliform load to meet water quality standards were simulated using the HSPF model.

5.3.1 Wasteload Allocation

There is one permitted point source discharge in the Mill Creek watershed. The Riner Sewage Treatment Plant (STP) is permitted to discharge 100,000 gallons of treated water at a fecal coliform concentration of 200 cfu/100 ml. For this TMDL, the wasteload allocation for the Riner STP is to maintain the discharge and fecal coliform concentration at their permit levels (100,000 gallons per day and 200 cfu/100 ml) (Table 5-1).

Table 5-1: Mill Creek Wasteload Allocation

Permit Number	Existing Load (cfu/day)	Allocated Load (cfu/day)	Percent Reduction
VA 0024040	7.19E+8	7.19E+8	0%

5.3.2 Load Allocation

The reduction of loading from nonpoint sources, including livestock and wildlife direct deposition is incorporated into the load allocation. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario. The scenarios considered are presented in Table 5-2 and can be summarized as follows:

- Scenario 0 represents the existing loading, which is no reduction of any of the sources;
- Scenario 1 represents elimination of the human sources (septic systems and straight pipes),
- Scenario 2 represents elimination of the human sources (septic systems and straight pipes) and 50 percent reduction of the direct instream loading from livestock;
- Scenario 3 represents elimination of the human sources (septic systems and straight pipes) and a 75 percent reduction of the direct instream loading from livestock;
- Scenario 4 represents elimination of the human sources (septic systems and straight pipes) as well as the direct instream loading from livestock;
- Scenario 5 represents the direct instream loading from wildlife (all other sources are eliminated);
- Scenario 6 represents elimination of the human sources (septic systems and straight pipes) and the direct instream loading from livestock and a 50 percent reduction of the direct in-stream loading from wildlife;
- Scenario 7 represents elimination of the human sources (septic systems and straight pipes) and the direct instream loading from livestock and a 75 percent reduction of the direct in-stream loading from wildlife;

- Scenario 8 represents elimination of the human sources (septic systems and straight pipes) and the direct instream loading from livestock and an 80 percent reduction of the direct in-stream loading from wildlife; and
- Scenario 9 represents elimination of the human sources (septic systems and straight pipes) and the direct instream loading from livestock, an 80 percent reduction of the direct in-stream loading from wildlife, and a 20 percent reduction of the loading from nonpoint sources.

Table 5-2: Mill Creek Load Allocation Scenarios

Scenario	Reduction in Loadings from Existing Conditions (%)				
	Failing Septic Systems and Pipes	Direct Livestock	Nonpoint Sources	Pets	Direct Wildlife
0	-	-	-	-	-
1	100	-	-	-	-
2	100	50	-	-	-
3	100	75	-	-	-
4	100	100	-	-	-
5	100	100	100	100	-
6	100	100	-	-	50
7	100	100	-	-	75
8	100	100	-	-	80
9	100	100	20	-	80

For the hydrologic period from January 1995 to December 2000, the fecal coliform loading and the instream fecal coliform concentrations were estimated for each potential scenario using the developed HSPF model of the Mill Creek watershed. The estimated load reductions resulting from these allocation scenarios are presented in Table 5-3. Table 5-3 shows the estimated load reduction under each scenario and the percent of days the 190 cfu/100 ml water quality standard was violated. The following conclusions can be made:

1. Under existing conditions, the water quality standard was violated all the time (Scenario 0);

2. Elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading would result in a 99 percent violation of the water quality standard (Scenario 4);
3. Allocating only direct instream loading from wildlife results in a 90 percent violation of the water quality standard (Scenario 5); and
4. No violation of the water quality standard was achieved in Scenario 9, in which there is complete elimination of the human sources (failed septic systems and straight pipes) and livestock direct deposition, an 80 percent reduction of the wildlife direct loading, and 20 percent reduction of nonpoint sources of fecal coliform.

Table 5-3: Mill Creek Load Reduction under 30-Day Geometric Mean Standard

Scenario Number	Reduction in Loadings from Existing Conditions (%)					% Days Geometric Mean exceed 190 cfu/100ml
	Failed Septic Systems and Pipes	Direct Livestock	Nonpoint Sources	Pets	Direct Wildlife	
0	**-**	**-**	**-**	**-**	**-**	**100**
1	100	-	-	-	-	100
2	100	50	-	-	-	100
3	100	75	-	-	-	100
4	100	100	-	-	-	99
5	100	100	100	100	-	90
6	100	100	-	-	50	83.7
7	100	100	-	-	75	12.2
8	100	100	-	-	80	1.4
9	100	100	20	-	80	0

5.4 TMDL Summary

Based on load allocation scenario analysis, a TMDL allocation plan to meet the 30-day geometric mean water quality standard goal of 190 cfu/100 ml requires:

- 100 percent reduction of the human sources (failed septic systems and straight pipes);
- 100 percent reduction of the direct instream loading from livestock;
- 80 percent reduction of the fecal coliform loading from wildlife; and

- 20 percent reduction of the fecal coliform loading from nonpoint sources.

Table 5-5 shows the distribution of the annual average fecal coliform load under existing conditions and under the TMDL allocation by land use and source. The monthly distribution of these loads is presented in Appendix C.

Table 5-4: Distribution of Annual Average Fecal Coliform Load under Existing Conditions

Land Use/Source	Annual Average Fecal Coliform Loads		Percent Reduction
	Existing	Allocation	
Forest	4.89E+11	4.89E+11	0%
Low Density Residential	1.35E+12	1.35E+12	0%
Med Intensity Residential	7.47E+11	7.47E+11	0%
Pasture/Hay	5.03E+14	4.02E+14	20%
Unimproved Pasture/Hay	2.50E+09	2.00E+09	20%
Row Crops	6.58E+11	5.26E+11	20%
Commercial/Industrial/Transportation	5.19E+10	5.19E+10	0%
Farmstead	7.27E+11	7.27E+11	0%
Septic load	1.13E+11	0	100%
Direct deposition from cattle	4.25E+14	0	100%
Direct deposition from wildlife	6.66E+13	1.33E+13	80%
Point Source (1)	2.62E+11	2.62E+11	0

Figure 5-1 shows the existing fecal coliform loading and the fecal coliform loading after applying the allocation scenario 9. A summary of the fecal coliform TMDL allocation plan loads for Mill Creek is presented in Table 5-6.

Figure 5-1: Existing and Allocated Fecal Coliform Loadings

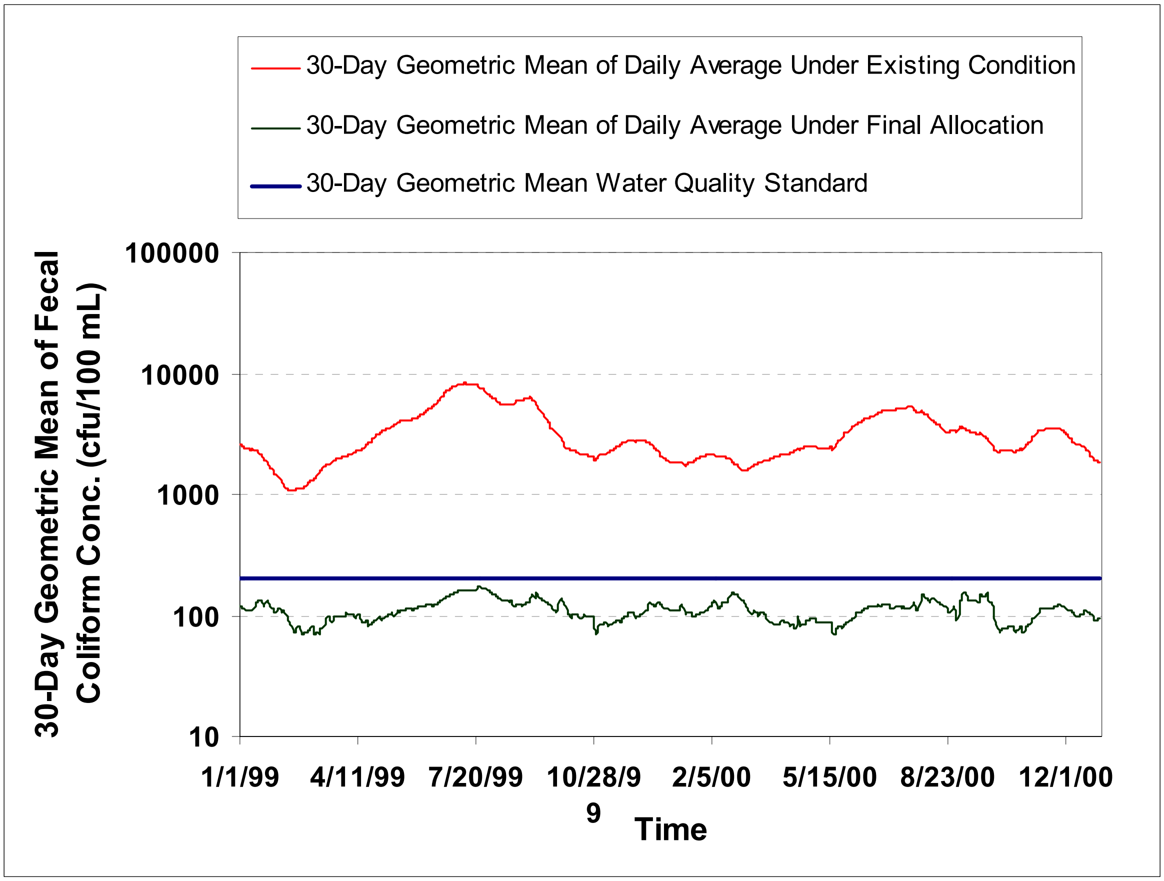


Table 5-5: Mill Creek TMDL Allocation Plan Loads (cfu/year)

Point Sources (WLA)	Nonpoint sources (LA)	Margin of safety (MOS)	TMDL
2.62E+11	4.18E+14	2.32E+12	4.22E+14

6.0 Implementation

6.1 TMDL Implementation

The Commonwealth intends for this TMDL to be voluntarily implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are:

> 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved;
>
> 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support;
>
> 4) it helps to ensure the most cost effective practices are implemented initially, and
>
> 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

For the same scenarios presented in Table 6-1, the violation of the instantaneous water quality standard was also considered. The table shows allocation scenarios and the percent of days the instantaneous water quality standard of 1,000 cfu/100 ml was violated. The following conclusions can be made:

1. Under existing conditions, the water quality standard was violated 94.8 percent of the time (Scenario 0);
2. Elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading would result in a 13.8 percent violation of the water quality standard (Scenario 4);
3. The wildlife loading would result in 0.1 percent violation of the water quality standard (Scenario 5); and
4. The goal of not violating the instantaneous water quality standard more than 10 percent of the time would be achieved in Scenario 7. This scenario includes complete elimination of the human sources (failed septic systems and straight pipes) and livestock direct instream deposition, an 80 percent reduction of the

wildlife direct load, and a 20 percent reduction of the load from nonpoint sources of fecal coliform this would be the stage or phase one implementation allocation scenario.

Table 6-1: Mill Creek Load Reduction under Instantaneous Standard

Scenario Number	Reduction in Loadings from Existing Conditions (%)					Percent of Days Exceed Inst. Standard (1000 cfu/100ml)
	Failing Septic Systems and Pipes	Direct Livestock	Nonpoint Sources	Pets	Direct Wildlife	
0	-	-	-	-	-	**94.8**
1	100	-	-	-	-	94.8
2	100	50	-	-	-	83.8
3	100	75	-	-	-	62
4	100	100	-	-	-	13.8
5	100	100	100	100	-	0.1
6	100	100	-	-	50	12.3
7	**100**	**100**	**20**	**-**	**80**	**9.3**

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan as outlined below. While specific stage I goals for BMP implementation will be established as part of the implementation plan development process, some general guidelines and suggestions are outlined below.

- elimination of the human sources (failed septic systems and straight pipes)
- elimination of livestock direct instream deposition,
- 80 percent reduction of the wildlife direct load, and
- 20 percent reduction of the load from nonpoint sources of fecal coliform.

In general, the Commonwealth intends for the required reductions to be implemented in an iterative process that addresses the sources with the largest impact on water quality. For example, the most promising management practice in agricultural areas of the watershed is livestock exclusion from streams. This has been shown to be very effective in lowering fecal coliform concentrations in streams, both from the cattle deposits themselves and from additional buffering in the riparian zone. Additionally, reducing the human bacteria loading from failing septic systems and straight pipes should be a focus during the first stage because of its health implications.

6.2 Reasonable Assurance for Implementation

6.2.1 Follow-Up Monitoring

DEQ will continue to monitor Mill Creek in accordance with its ambient monitoring program. DEQ and DCR will continue to use data from these monitoring stations to evaluate reductions in fecal bacteria counts and the effectiveness of the TMDL in attaining and maintaining water quality standards.

6.2.2 Regulatory Framework

This TMDL is the first step toward the expeditious attainment of water quality standards. The second step will be to develop a TMDL implementation plan, and the final step is to implement the TMDL until water quality standards are attained.

Section 303(d) of the Clean Water Act and current EPA regulations do not require the development of implementation strategies; however, including implementation plans as a TMDL requirement has been discussed for future federal regulations. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act directs DEQ in Section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters." The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

6.3 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. In future years, increases in Section 319 funding will be targeted toward TMDL implementation and watershed restoration. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement Program, the state's revolving loan program, and the Virginia Water Quality Improvement Fund.

6.4 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all of the sources of fecal coliform (other than wildlife), the stream will not attain standards. As is the case for Mill Creek, TMDL alloccation reductions of this magnitude are not realistic and do not meet EPA's guidance for reasonable assurance. Based on the water quality modeling, many of these streams will not be able to attain standards without some reduction in wildlife load. **Virginia and**

EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. This is obviously an impractical action. While managing over-populations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. In such a case, after demonstrating that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs, the state may decide to re-designate the stream's use for secondary contact recreation or to adopt site specific criteria based on natural background levels of fecal coliforms. The state must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs through a so-called Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process.

Based on the above, EPA and Virginia have developed a TMDL strategy to address the wildlife issue. The first step in this strategy is to develop an interim reduction goal such as in Table 5-4. The pollutant reductions for the interim goal are applied only to controllable, anthropogenic sources identified in the TMDL, setting aside any control strategies for wildlife. During the first implementation phase, all controllable sources would be reduced to the maximum extent practicable using the staged approach outlined above. Following completion of the first phase, DEQ would re-assess water quality in the stream to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the second phase because the water quality standard exceedances attributed to wildlife in the model are very small and infrequent and fall within the margin of error.

7.0 Public Participation

The development of the Mill Creek TMDL would not have been possible without public participation. The first public meeting was held in the Town of Riner on December 4, 2001 to discuss the process for TMDL development, present the listed segment of Mill Creek and present the data that caused the segment to be on the 303(d) list, identify the review the data and information needed in the TMDL development, and present preliminary bacterial source tracking data. Forty-three people attended this meeting. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register*. A public notice newsletter was prepared by DEQ. A public meeting notice was published in the *New River Current* on November 24, 2001. There was a 30-day public comment period during which no written comments were received.

The second public meeting was held in the Town of Riner on February 19, 2002 to review the TMDL process; present the livestock, wildlife, and pet inventories; present the fecal coliform sources assessment and the calculation used to estimate the total available fecal coliform load; present and explain the assumptions used in the calculations; and present the HSPF model hydrological calibration and the goodness of fit. Twenty-two people attended the meeting. Copies of the presentation were available for public distribution. The meeting was public noticed in the Virginia Register. A public meeting notice newsletter was prepared by DEQ and mailed to the watershed residents. A public meeting notice was published in the *New River Current* on February 12, 2002. During the 30-day comment period, one written comment was received.

The third public meeting was held in the Town of Riner on March 26, 2002 to discuss the draft TMDL; 48 people attended. Copies of the presentation and an executive summary of the TMDL were available for public distribution. The meeting was public noticed in the Virginia Register. A public meeting notice newsletter was prepared by DEQ and mailed to the watershed residents. A public meeting notice was published in the *New*

River Current on March 20, 2002. So far, no written comment has been received during the 30-day comment period.

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Glossary

Allocations. Allocations are that portion of a receiving water's loading capacity that is attributed to one of its existing or future sources (nonpoint or point) of pollution or to natural background sources. (Wasteload allocation (WLA) is that portion of the loading capacity allocated to an existing or future point source and a load allocation (LA) is that portion allocated to an existing or future nonpoint source or to natural background source. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)

Ambient water quality. Concentration of water quality constituent as measured within the waterbody.

Assimilative capacity. The amount of pollutant load that can be discharged to a specific waterbody without exceeding water quality standards. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharges substance without impairing water quality or harming aquatic life.

Bacteria. Single-celled microorganisms that lack a fully-defined nucleus and contain no chlorophyll. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources). A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best management practices (BMPs). Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Calibration. The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Channel. A natural stream that conveys water; a ditch or channel excavated for the flow of water.

Clean Water Act (CWA). The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.

Coliform bacteria. See Total coliform bacteria.

Combined sewer system (CSS). Sewer system that receives both domestic wastewater and stormwater and conducts the mixture to a treatment facility.

Concentration. Amount of a substance or material in a given unit volume of solution. Usually measured in milligrams per liter (mg/l) or parts per million (ppm).

Contamination. Act of polluting or making impure; any indication of chemical, sediment, or biological impurities.

Cost-share program. Program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs are paid by the producer.

Critical condition. The combination of environmental factors that results in just meeting the water quality criterion and has an acceptably low frequency of occurrence.

Cross-sectional area. Wet area of a waterbody normal to the longitudinal component of the flow.

Cryptosporidium. See protozoa.

Decay. Gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.

Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

Deterministic model. A model that does not include built-in variability: same input will always equal the same output.

Die-off rate. The first-order decay rate for bacteria, pathogens, and viruses. Die-off depends on the particular type of water body (i.e. stream, estuary , lake) and associated factors that influence mortality.

Dilution. Addition of less concentrated liquid (water) that results in a decrease in the original concentration.

Direct runoff. Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.

Discharge. Flow of surface water in a stream or canal or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.

Discharge permits (NPDES). A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. It is called the NPDES because the permit process was established under the National Pollutant

Discharge Elimination System, under provisions of the Federal Clean Water Act.

Effluent. Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.

Effluent limitation. Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.

Endpoint. An endpoint is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints that are commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance. A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints.

Enteric. Of or within the gastrointestinal tract.

Enterococci. A subgroup of the fecal streptococci that includes S. faecalis and S. faecium. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 C and 45 C. Enterococci are a valuable bacterial indicator for determining the extent of fecal contamination of recreational surface waters.

Epidemiology. All the elements contributing to the occurrence or non-occurrence of a disease in a population; ecology of a disease.

Escherichia coli. A subgroup of the fecal coliform bacteria. *E. coli* is part of the normal intestinal flora in humans and animals and is, therefore, a direct indicator of fecal contamination in a waterbody. The O157 strain, sometimes transmitted in contaminated waterbodies, can cause serious infection resulting in gastroenteritis. See Fecal coliform bacteria.

Existing use. Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).

Fecal coliform bacteria. A subset of total coliform bacteria that are present in the intestines or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of water. They are measured by running the standard total coliform test at an elevated temperature (44.5 °C). Fecal coliform is approximately 20% of total coliform. See also Total coliform bacteria.

Fecal streptococci. These bacteria include several varieties of streptococci that originate in the gastrointestinal tract of warm-blooded animals such as humans (*Streptococcus faecalis*) and domesticated animals such as cattle (*Streptococcus bovis*) and horses (*Streptococcus equinus*).

Feedlot. A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.

Flux. Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.

Giardia lamblia. See protozoa.

Gradient. The rate of decrease (or increase) of one quantity with respect to another; for example, the rate of decrease of temperature with depth in a lake.

Groundwater. The supply of fresh water found beneath the earth s surface, usually in aquifers, which supply wells and springs. Because groundwater is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.

Hydrology. The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Indicator. Measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.

Indicator organism. Organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.

Infectivity. Ability to infect a host.

Initial mixing zone. Region immediately downstream of an outfall where effluent dilution processes occur. Because of the combined effects of the effluent buoyancy, ambient stratification, and current, the prediction of initial dilution can be involved.

Insolation. Exposure to the sun's rays.

Irrigation. Applying water or wastewater to land areas to supply the water and nutrient needs of plants.

Karst geology. Solution cavities and closely-spaced sinkholes formed as a result of dissolution of carbonate bedrock.

Land application. Discharge of wastewater onto the ground for treatment or reuse. (See: irrigation)

Leachate. Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, groundwater, or soil.

Load, Loading, Loading rate. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.

Load allocation (LA). The portion of a receiving water s loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished. (40 CFR 130.2(g))

Loading capacity (LC). The greatest amount of loading that a water can receive without violating water quality standards.

Low-flow. Stream flow during time periods where no precipitation is contributing to runoff to the stream and contributions from groundwater recharge are low. Low flow results in less water available for dilution of pollutants in the stream. Due to the limited flow, direct discharges to the stream dominate during low flow periods. Exceedences of water quality standards during low flow conditions are likely to be caused by direct discharges such as point sources, illicit discharges, and livestock or wildlife in the stream.

Margin of Safety (MOS). A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

Mass balance. An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.

Mass loading. The quantity of a pollutant transported to a waterbody.

Mathematical model. A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one, or more, individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.

Mitigation. Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those which restore, enhance, create, or replace damaged ecosystems.

Monitoring. Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

National Pollutant Discharge Elimination System (NPDES). The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318, and 405 of the Clean Water Act.

Natural background levels. Natural background levels represent the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.

Natural waters. Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.

Nonpoint source. Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Numeric Targets. A measurable value determined for the pollutant of concern which is expected to result in the attainment of water quality standards in the listed waterbody.

Organic matter. The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substance synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.

Outfall. Point where water flows from a conduit, stream, or drain.

Pathogen. Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Permit. An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

Permit Compliance System (PCS). Computerized management information system which contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.

Phased approach. Under the phased approach to TMDL development, LAs and WLAs are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.

Point source. Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollutant. Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water. (CWA Section 502(6)).

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Protozoa. Single-celled organisms that reproduce by fission and occur primarily in the aquatic environment. Waterborne pathogenic protozoans of primary concern include Giardia lamblia and Cryptosporidium, both of which affect the gastrointestinal tract.

Public comment period. The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

Publicly Owned Treatment Works (POTW). Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

Raw sewage. Untreated municipal sewage.

Receiving waters. Creeks, streams, rivers, lakes, estuaries, groundwater formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

Residence time. Length of time that a pollutant remains within a section of a waterbody. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.

Respiration. Biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of the energy required to sustain life; during respiration, oxygen is consumed and carbon dioxide is released.

Restoration. Return of an ecosystem to a close approximation of its condition prior to disturbance.

Runoff. That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Safe Drinking Water Act. The Safe Drinking Water Act authorizes EPA to set national health-based standards for drinking water to protect against both naturally occurring and man-made contaminants that may be found in drinking water. EPA, states, and water systems then work together to make sure these standards are met.

Sanitary sewer overflow (SSO). When wastewater treatment systems overflow due to unforseen pipe blockages or breaks, unforseen structural, mechanical, or electrical failures, unusually wet weather conditions, insufficient system capacity, or a deteriorating system.

Scoping modeling. Involves simple, steady-state analytical solutions for a rough analysis of the problem.

Septic system. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a system of tile lines or a pit for disposal of the liquid effluent. The solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Sewer. A channel or conduit that carries wastewater and stormwater runoff from the source to a treatment plant or receiving stream. “Sanitary” sewers carry household, industrial, and commercial waste. “Storm” sewers carry runoff from rain or snow. “Combined” sewers handle both.

Simulation. Refers to the use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Slope. The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04); degrees (2 degrees 18 minutes), or percent (4 percent).

Stakeholder. Those parties likely to be affected by the TMDL.

Steady-state model. Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations.

STORET. U.S. Environmental Protection Agency (EPA) national water quality database for STORage and RETrieval (STORET). Mainframe water quality database that includes physical, chemical, and biological data measured in waterbodies throughout the United States.

Storm runoff. Stormwater runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or waterbodies or is routed into a drain or sewer system.

Stormwater. The portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels or pipes into a defined surface water channel, or a constructed infiltration facility.

Stormwater management models (SWMM). USEPA mathematical model that simulates the hydraulic operation of the combined sewer system and storm drainage sewershed.

Stratification (of waterbody). Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter water overlaying heavier and denser water.

Stressor. Any physical, chemical, or biological entity that can induce an adverse response.

Surface runoff. Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.

Surface water. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other groundwater collectors directly influenced by surface water.

Technology-based limits. Industry-specified effluent limitations applied to a discharge when it will not cause a violation of water quality standards at low stream flows. Usually applied to discharges into large rivers.

Three-dimensional model (3-D). Mathematical model defined along three spatial coordinates where the water quality constituents are considered to vary over all three spatial coordinates of length, width, and depth.

Topography. The physical features of a surface area including relative elevations and the position of natural and man-made features.

Total coliform bacteria. A particular group of bacteria, found in the feces of warm-blooded animals, that are used as indicators of possible sewage pollution. They are characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming, rod-shaded bacteria which ferment lactose with gas formation within 48 hours at 35° . Note that many common soil bacteria are also total coliforms, but do not indicate fecal contamination. See also fecal coliform bacteria.

Total Maximum Daily Load (TMDL). The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, and a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard

Tributary. A lower order stream compared to a receiving waterbody. “Tributary to” indicates the largest stream into which the reported stream or tributary flows.

Turbidity. The amount of light that is scattered or absorbed by a fluid.

Two-dimensional model (2-D). Mathematical model defined along two spatial coordinates where the water quality constituents are considered averaged over the third remaining spatial coordinate. Examples of 2-D models include descriptions of the variability of water quality properties along: (a) the length and width of a river that incorporates vertical averaging or (b) length and depth of a river that incorporates lateral averaging across the width of the waterbody.

Urban runoff. Water containing pollutants like oil and grease from leaking cars and trucks; heavy metals from vehicle exhaust; soaps and grease removers; pesticides from gardens; domestic animal waste; and street debris, which washes into storm drains and enters surface waters.

Validation (of a model). Process of determining how well the mathematical representation of the physical processes of the model code describes the actual system behavior.

Verification (of a model). Testing the accuracy and predictive capabilities of the calibrated model on a data set independent of the data set used for calibration.

Virus. Submicroscopic pathogen consisting of a nucleic acid core surrounded by a protein coat. Requires a host in which to replicate (reproduce).

Wasteload allocation (WLA). The portion of a receiving water s loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).

Wastewater. Usually refers to effluent from a sewage treatment plant.

Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water in order to remove, reduce, or neutralize contaminants.

Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

Water quality criteria. Elements of state water quality standards expressed as constituent concentrations, levels, or narrative statement, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use.

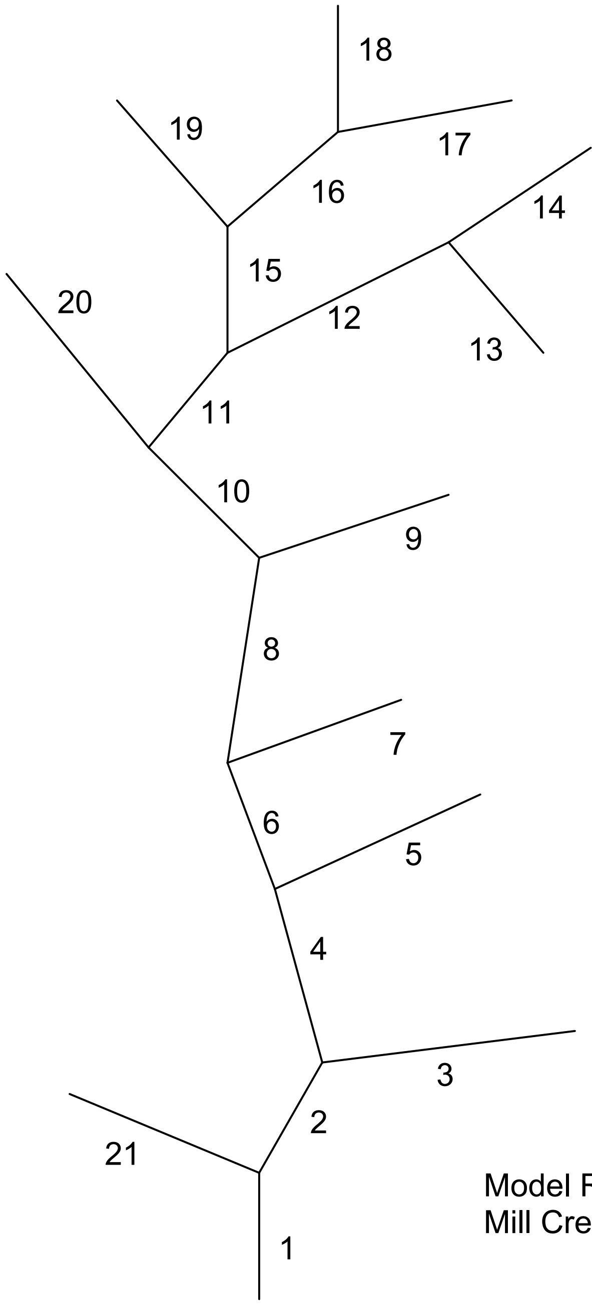
Water quality standard. State or federal law or regulation consisting of a designated use or uses for the waters of the United States, water quality criteria for such waters based upon such uses, and an antidegradation policy and implementation procedures. Water quality standards protect the public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act.

Watershed. A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Wetlands. An area that is constantly or seasonally saturated by surface water or groundwater with vegetation adapted for life under those soil conditions, as in swamps, bogs, fens, marshes, and estuaries.

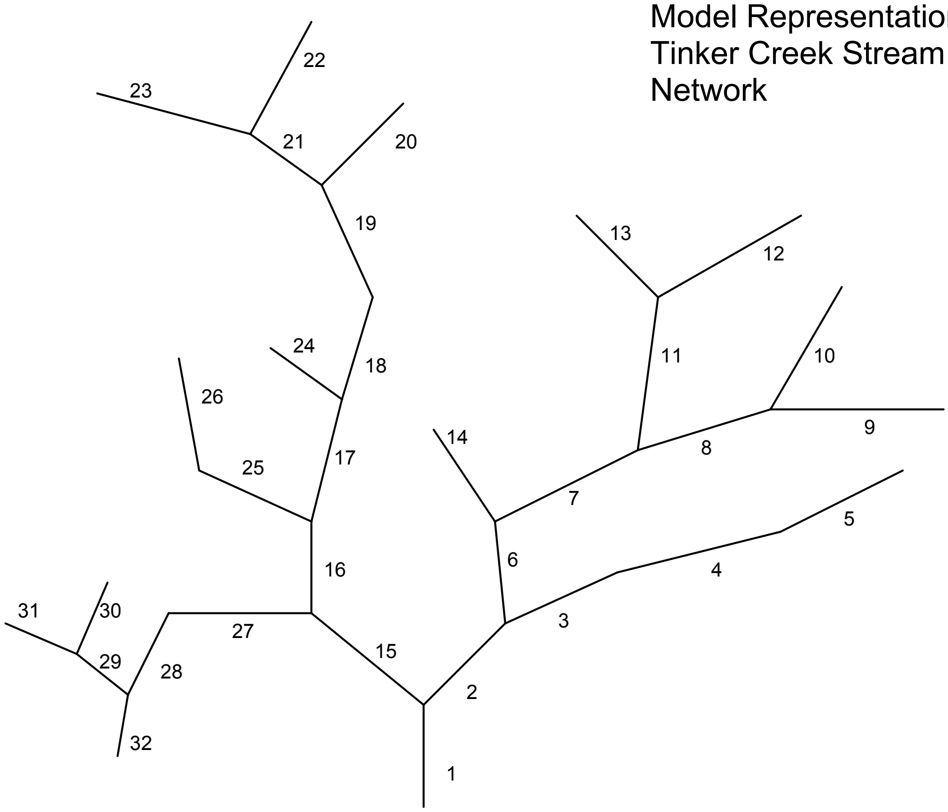
Appendix A

Model Representation of Stream Reach Networks



Model Representation of
Mill Creek Stream Reach Network

Model Representation of Tinker Creek Stream Reach Network



Appendix B

Monthly Fecal Coliform Build-up Rates

Table B-1: Mill Creek Monthly Build-up rates cfu/ac/day

Land use	JAN	FEB	MAR	APR	MAY	JUN
Forest	7.87E+07	7.87E+07	7.87E+07	7.87E+07	7.87E+07	7.87E+07
Low Intensity Reside	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09
Pasture/Hay	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10
Row Crops	8.00E+07	1.00E+08	1.00E+08	2.00E+08	1.00E+08	1.00E+08
High Intensity Resid	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09
Unimproved Pasture	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10
Comm/Ind/Trnsprt	7.56E+07	7.56E+07	7.56E+07	7.56E+07	7.56E+07	7.56E+07
Farmstead	1.13E+09	1.13E+09	1.13E+09	1.13E+09	1.13E+09	1.13E+09

Table B-2: Mill Creek Monthly Build-up rates cfu/ac/day

Land use	JUL	AUG	SEP	OCT	NOV	DEC
Forest	7.87E+07	7.87E+07	7.87E+07	7.87E+07	7.87E+07	7.87E+07
Low Intensity Reside	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09
Pasture/Hay	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10
Row Crops	1.00E+08	1.00E+08	1.00E+08	2.00E+08	1.00E+08	8.00E+07
High Intensity Resid	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09
Unimproved Pasture	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10
Comm/Ind/Trnsprt	7.56E+07	7.56E+07	7.56E+07	7.56E+07	7.56E+07	7.56E+07
Farmstead	1.13E+09	1.13E+09	1.13E+09	1.13E+09	1.13E+09	1.13E+09

Table B-3:Mill Creek Monthly Direct Deposition Rate

Month	Direct deposition loads from cattle (cfu/month)	Direct deposition loads from Wildlife (cfu/month)	Direct deposition loads from Human (cfu/month)
1	1.99089E+13	5.55E+12	9.42E+09
2	1.79822E+13	5.55E+12	9.42E+09
3	3.07095E+13	5.55E+12	9.42E+09
4	4.01733E+13	5.55E+12	9.42E+09
5	4.15124E+13	5.55E+12	9.42E+09
6	5.06407E+13	5.55E+12	9.42E+09
7	5.23287E+13	5.55E+12	9.42E+09
8	5.23287E+13	5.55E+12	9.42E+09
9	4.01733E+13	5.55E+12	9.42E+09
10	3.07095E+13	5.55E+12	9.42E+09
11	2.97189E+13	5.55E+12	9.42E+09
12	1.99089E+13	5.55E+12	9.42E+09

Appendix C

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

Table C-1 **Fecal Coliform Load: Existing Condition (counts/acre/month)**

Month	Comm/Ind/Trnsprt	Farmstead	Forest	Low Intensity Resid	Intensity Resid	Pasture/Hay	Row Crops	Unimproved Pasture
1	1.10E+08	1.48E+09	6.18E+07	1.45E+09	1.45E+09	1.92E+10	1.14E+08	2.02E+10
2	6.67E+07	8.40E+08	3.32E+07	8.24E+08	8.24E+08	9.98E+09	8.84E+07	1.07E+10
3	6.69E+07	8.83E+08	4.01E+07	8.66E+08	8.66E+08	1.24E+10	1.14E+08	1.31E+10
4	3.34E+07	4.36E+08	1.35E+07	4.27E+08	4.27E+08	6.59E+09	5.63E+07	7.12E+09
5	8.27E+06	9.51E+07	4.02E+06	9.32E+07	9.32E+07	1.28E+09	1.10E+07	1.41E+09
6	6.43E+07	8.44E+08	2.56E+07	8.27E+08	8.27E+08	1.24E+10	9.70E+07	1.34E+10
7	1.65E+07	2.09E+08	5.06E+06	2.05E+08	2.05E+08	2.97E+09	2.73E+07	3.26E+09
8	2.33E+07	3.01E+08	8.03E+06	2.95E+08	2.95E+08	4.37E+09	3.82E+07	4.76E+09
9	6.62E+07	8.83E+08	3.40E+07	8.65E+08	8.65E+08	1.40E+10	1.04E+08	1.49E+10
10	3.86E+06	3.48E+07	1.80E+06	3.41E+07	3.41E+07	4.17E+08	5.50E+06	4.63E+08
11	2.84E+07	3.60E+08	9.48E+06	3.53E+08	3.53E+08	4.27E+09	2.52E+07	4.70E+09
12	9.36E+06	9.47E+07	3.84E+06	9.29E+07	9.29E+07	9.38E+08	6.74E+06	1.04E+09

Table C-2 **Fecal Coliform Load: Allocation Run (counts/acre/month)**

Month	Comm/Ind/Trnsprt	Farmstead	Forest	Low Intensity Resid	Intensity Resid	Pasture/Hay	Row Crops	Unimproved Pasture
1	1.10E+08	1.48E+09	6.18E+07	1.45E+09	1.45E+09	1.53E+10	9.09E+07	1.62E+10
2	6.67E+07	8.40E+08	3.32E+07	8.24E+08	8.24E+08	7.99E+09	7.07E+07	8.57E+09
3	6.69E+07	8.83E+08	4.01E+07	8.66E+08	8.66E+08	9.91E+09	9.09E+07	1.05E+10
4	3.34E+07	4.36E+08	1.35E+07	4.27E+08	4.27E+08	5.27E+09	4.50E+07	5.69E+09
5	8.27E+06	9.51E+07	4.02E+06	9.32E+07	9.32E+07	1.02E+09	8.78E+06	1.13E+09
6	6.43E+07	8.44E+08	2.56E+07	8.27E+08	8.27E+08	9.91E+09	7.76E+07	1.07E+10
7	1.65E+07	2.09E+08	5.06E+06	2.05E+08	2.05E+08	2.38E+09	2.19E+07	2.61E+09
8	2.33E+07	3.01E+08	8.03E+06	2.95E+08	2.95E+08	3.50E+09	3.06E+07	3.81E+09
9	6.62E+07	8.83E+08	3.40E+07	8.65E+08	8.65E+08	1.12E+10	8.28E+07	1.19E+10
10	3.86E+06	3.48E+07	1.80E+06	3.41E+07	3.41E+07	3.34E+08	4.40E+06	3.71E+08
11	2.84E+07	3.60E+08	9.48E+06	3.53E+08	3.53E+08	3.42E+09	2.02E+07	3.76E+09
12	9.36E+06	9.47E+07	3.84E+06	9.29E+07	9.29E+07	7.51E+08	5.39E+06	8.32E+08

Appendix D

Sensitivity Analysis

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Mill Creek flows through a rural setting. Potential sources of fecal coliform include point sources and nonpoint (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model input parameters on the fecal coliform annual loading and the fecal coliform concentration in Mill Creek. For the hydrologic period, October 1997 to September 1998, the model was run under various land based and the direct deposition loading scenarios which include the following:

- 10 percent increase in land based loads
- 10 percent decrease in land based loads
- 100 percent increase in land based loads
- 10 percent decrease in land based loads
- 10 percent increase in direct deposition loads
- 10 percent decrease in direct deposition loads
- 100 percent increase in direct deposition loads
- 100 percent decrease in direct deposition loads

The results of the sensitivity analysis are presented in Figures D-1, D-2, and D-3. Based on these figures it can be seen that a reduction of the direct deposition load is more effective in reducing the instream fecal coliform concentration under low flow condition and consequently meeting the water quality targets for Mill Creek.

Figure D-1:

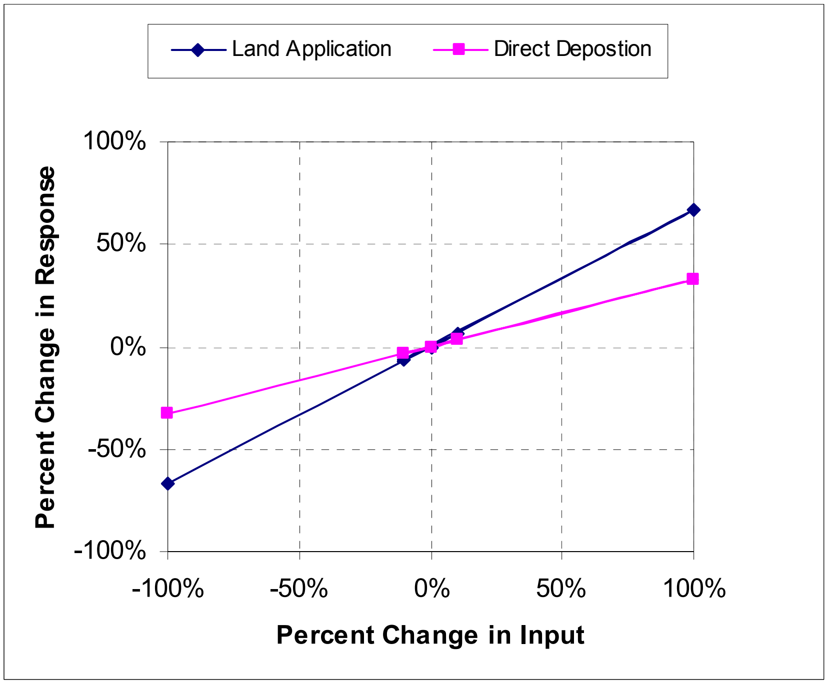


Figure D-2

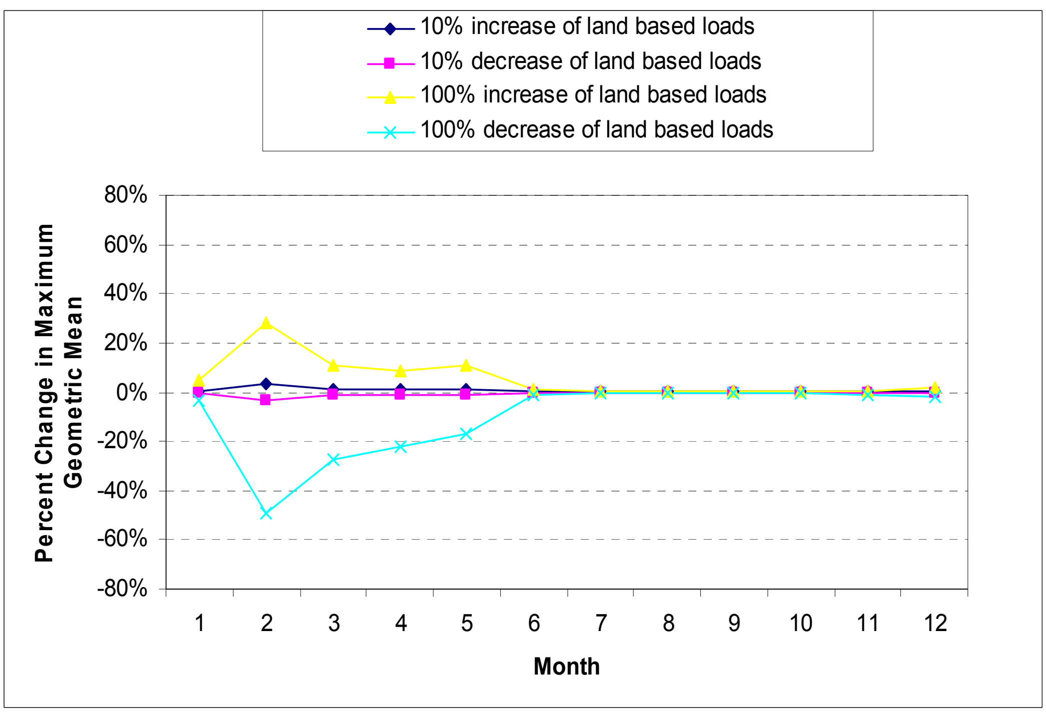
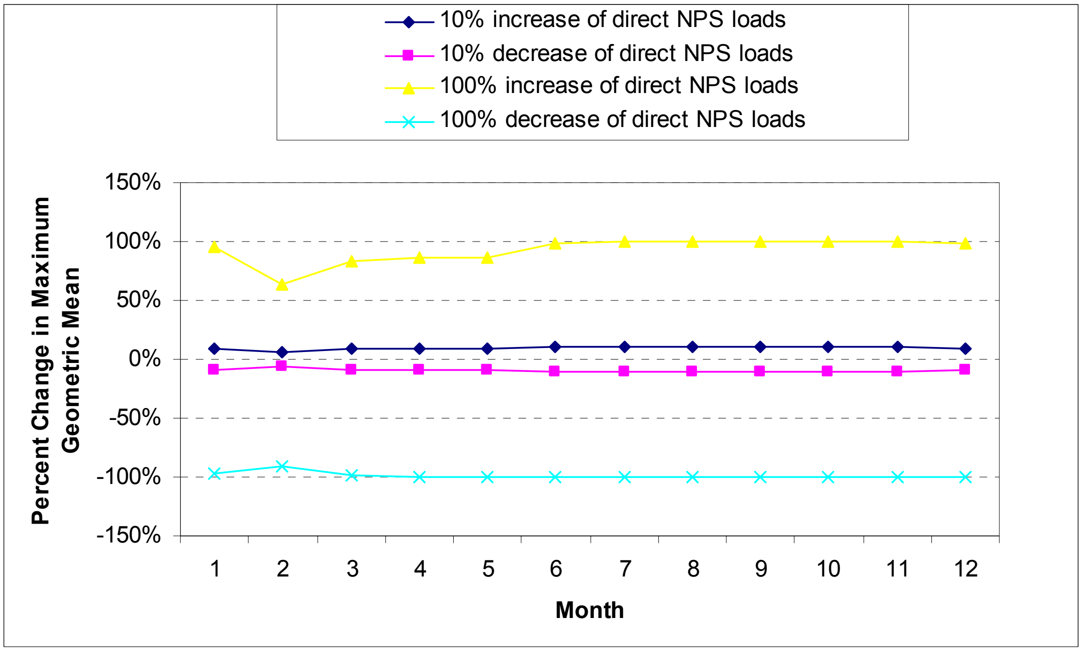


Figure D-3


10% increase of direct NPS loads
10% decrease of direct NPS loads
100% increase of direct NPS loads
100% decrease of direct NPS loads
Percent Change in Maximum Geometric Mean
150%
100%
50%
0%
-50%
-100%
-150%
1
2
3
4
5
6
7
8
9
10
11
12
Month